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A Method of Determining Sugar Cane Quality in Louisiana.

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ABSTRACT

The high incidence of sugar cane payment systems throughout the world in which cane payment is based on actual or inferred quality of the cane has placed a premium on accurate methods of cane quality determination. Unfortunately, the current cane evaluation systems were developed when cane was hand-cut, fresh, and trash-free. These methods are no longer applicable where the harvesting operations are mechanized. In Louisiana where the cutting and loading operations are 100 per cent mechanical, cane washing facilities generally precede the mill tandem. Accordingly, cane samples are removed before washing and are processed in three-roll sample mills. However, the quality of the cane as determined from the sample processing is still expressed in terms of the apparent sucrose (or pol) and purity of the normal juice – normal juice being defined as juice extracted without the addition of maceration water. In addition to failing to account for the <u>quantity</u> of juice in the sample, the normal juice system requires factors of questionable accuracy which relate the quality of the sample mill, crusher, and normal juice. In other cane growing areas of the world, fiber per cent cane is used in several systems of cane quality determination as a measure of the extractable juice in the cane. However, routine fiber determinations

for such purposes are time consuming and require considerable investment in laboratory personnel and equipment.

The method of cane quality determination and payment which was developed in these studies involves payment to the grower based on (1) the predicted recoverable sugar in the cane sample and (2) a standard split in returns for sugar between the grower and the factory. The recoverable sugar in each sample is determined by means of a recoverable sugar formula in which are incorporated (1) the sample mill Brix and pol extraction as determined from the quality and quantity of extracted juice, (2) factors relating the sample mill extraction to that of the factory which is corrected to a standard level of extraction efficiency, and (3) a standard boiling house retention. Inclusion of standard retention and extraction factors in the recoverable sugar formula thus provides a yield which is corrected to an area-wide level of factory efficiency — as determined from the quality of the cane specific to the factory area.

The experimental work in these studies covered means of processing the cane sample which should (1) simulate the pressure extraction of the factory tandem, (2) have a high degree of correlation with the factory extraction, and (3) be commercially feasible. Such devices included a three-roll hydraulically loaded cane sample mill, a screw press (an extruder type device for processing cotton seed), and a small hydraulic box press. Throughout the tests difficulty was experienced in maintaining a good material balance for the factory tandem. In view of this, it was felt that satisfactory correlation was demonstrated between the sample and the factory pol extraction; the correlation coefficients for the three-roll sample mill and the screw press ranged from 0.87 to 0.96. The box press showed rather good reproducibility on specially prepared cane of a high degree of fineness and uniformity. However, the sample-factory correlation was very poor on cane which was routinely prepared on available equipment.

The cost of cane as determined from the sample processing studies more accurately reflected the difference in the quantity of juice in the cane than the cost of cane by the conventional normal juice method.

Further work appears to be necessary on methods for withdrawing larger samples at the commercial mills in order to increase the accuracy of the cane evaluation.

CHAPTER I

INTRODUCTION

Increasingly, there has been a trend in the sugar cane growing areas of the world toward uniform cane payment systems. Such systems spell out in detail the contractual relationship between the farmer who grows the cane and the factory which converts the cane into the merchantable products of raw sugar, molasses and by-products. In recent years, the farmer-factory relationship has been generally expanded to include a third party – the government. The position of the latter has been generally that of the controlling voice in the triumverate. This is so to the extent that not only are the form and content of the cane payment system spelled out by law, but the administration of the system is vigorously enforced as well.

A key facet of the current cane payment systems is the provision for payment based on the quality of the cane which the farmer delivers to the factory. Provisions for adequately determining the quality of cane then become a primary requisite of a successful cane payment system. It is probably true that a cane payment system is no better than the method of cane quality determination which implements the payment system.

Unfortunately it is true that the methods of cane quality determination throughout the world have not kept pace with scientific and technological changes in the industry. Louisiana particularly is a case in point where the method of cane evaluation – based on the normal juice quality of the cane – was instituted in a period when the cane varieties were relatively few in number, and the factories received fresh, hand-cut, and relatively trash free cane. By contrast today, agronomic research has placed at the farmers' disposal numerous varieties of differing degrees of insect and disease resistance, fiber content, and early maturity and frost resistance characteristics. Probably of greater significance is the fact that the field operations in Louisiana are essentially 100 per cent mechanized. This has resulted in the delivery to the factory of machine-cut and loaded cane with attendant soil and trash – and of varying degrees of freshness or deterioration. Burning as a means of detrashing has merely added additional problems to those already cited.

This dissertation is, then, a study of a method or methods of cane quality determination which are applicable to present day conditions in the Louisiana sugar cane industry. Since the trend toward mechanization of field operations is proceeding at an accelerated pace in other cane growing areas of the world, this study is of more than local interest.

Although the methods of cane evaluation in actual practice have not kept pace with changes in the industry, rather extensive research on improved systems of cane quality determination is being conducted throughout the cane growing areas. Through the medium of the 1959 proceedings of the Tenth Congress of the International Society of Sugar Cane Technologists, considerable material on the subject was released - material which was not available to earlier Louisiana studies on cane quality determination. Chapter II, then, reviews recent literature on the subject.

The subject of cane quality determination is incomplete without an understanding of its relationship to the associated cane payment system. While cane quality determination has been extensively covered in the literature, relatively little information has been released on cane payment systems throughout the world. This in itself needs to be the subject of comprehensive research - a project beyond the scope of this study. As an alternative, Chapter III contains a <u>summary</u> of available information on cane payment systems throughout the world. This summary may clarify the inter-relation of cane payment and cane quality determination.

Chapter IV reviews the methods of cane quality determination and cane payment which are specific to Louisiana.

Cane quality determination has been the subject of continuing study at the Audubon Sugar Factory, and these investigations have been well documented. Chapter V summarizes this material as it affects the current research.

With the world-wide, Louisiana, and Audubon Sugar Factory data as a background, Chapter VI develops the logic leading to a proposed method of cane quality determination which would be applicable to Louisiana conditions.

Chapter VII covers the experimental procedure and equipment for validating the proposed cane evaluation method. The results of the study are presented and discussed in Chapter VIII. Chapter IX gives conclusions which are pertinent to the study.

CHAPTER II

METHODS OF SUGAR CANE QUALITY DETERMINATION

The subject of Sugar Cane Quality Determination becomes rather extensive when viewed in its entirety to include the related facets of sampling, testing, and evaluation. Although methods of testing and evaluation are of primary interest in this study, these cannot be properly interpreted without an understanding of the concomitant problem of sampling. Furthermore for a thorough appreciation of the subject, it is necessary to look into some of the sociological, economic, and statutory aspects of the industry in the geographic area under study. For these reasons, sections of this chapter dealing with the methods of cane quality determination in different areas of the world are divided into the following subsections where necessary:

> Sociological, Economic, and Legislative Systems - This sub-section covers such items as the incidence of independent cane farmers, the relative size of the independent farming operations, the methods of cane harvesting and transport, and statutory control of the industry.

Sampling - The methods of procuring or withdrawing the samples for subsequent inspection are briefly reviewed in this sub-section.

Testing and Evaluation - This sub-section covers the methods of preparing and inspecting the sample, and the methods of determining the quality of the consignment of cane from the sample inspections. In this sub-section, reference is made to the standard of cane quality. This is the unit which is used to define the quality of the cane. In Reunion, the standard of cane quality is SE, which is the recoverable sugar of 97^{o} titre per cent cane. Reference is also made to the cane quality formula. This is the formula which is used to evaluate the cane in the terms of the standard of cane quality. This formula generally equates some readily measurable quantities such as the crusher juice inspections - and possibly fiber per cent cane - to the standard of cane quality.

Historically, quality determinations for the purpose of cane payment have been concerned chiefly with the quality of the cane in the carrier to the mill tandem. Such determinations involved inspections of the crusher juice and - in more elaborate systems - the determination of the fiber content of the cane.

More recently, the growing incidence of mechanical harvesting – with the resultant trash and field soil accompanying the cane – has resulted throughout the industry in an increased frequency of cane washing installations at the factory. The resultant dilution of the crusher juice has made subsequent crusher juice inspections of doubtful value. The necessary recourse has been to analyze the cane <u>before it enters the carrier</u>.

As an outgrowth of problems in cane sampling which have resulted from mechanization of the field operations, extensive studies have been directed toward determing the quality of the cane from a sample removed before the cane enters the carrier. Such studies have drawn heavily on experience gained in agronomic research which was directed toward determining the yield of cane in the field.

By general usage, cane quality studies directed toward evaluating the cane <u>before</u> it enters the carrier or the milling process have been classified as <u>direct cane quality determination</u>. No such classification exists relative to quality determination of the cane <u>in</u> the carrier. For the purpose of this review, such methods are considered to be <u>indirect cane quality determination</u>.

This study is not intended to cover all the quality evaluation methods in use throughout the world. It does cover some of the better-known systems and recent developments in the subject. Primarily, those methods of cane quality determination are reviewed which form the basis for subsequent cane payment. However, certain methods used in agronomic research are applicable to cane payment systems and are also reviewed.

Among the cane growing areas that earlier recognized that the determination of cane quality is a necessary adjunct to an equitable cane payment system[1] Queensland, Australia is probably best-known for the indirect CCS system – CCS being a measure of the commercially recoverable sucrose in the cane. Because the CCS system is historically significant and extensively documented in the literature, and because the problems encountered by the Queensland industry in adapting the system to changing conditions of field harvest and increased factory capacity are common to the entire industry, the Queensland CCS system is reviewed first.

The Reunion SE method of indirect cane quality evaluation, which measures cane quality in terms of commercially recoverable sugar in the cane, is of interest because it has been recently developed and is based on a thorough and rigorous development of the conventional extraction and retention formulas.

The use of the Java Ratio, relating the sucrose content of the cane to the quality of the crusher juice, is probably the simplest method of indirect cane quality evaluation. The South African system uses the Java Ratio to determine the sucrose content of the cane directly from the sucrose content of a crusher juice sample. In

Jamaica, the purity of the crusher juice along with the Java Ratio and the crusher juice sucrose are incorporated into a formula to give the tons of cane per ton of 96° sugar (TC/TS).

In the Philippines, the Java Ratio and the crusher juice sucrose and purity are incorporated into a formula to give the predicted yield of commercial sugar per ton of cane – P/T or piculs of commercial sugar per ton of cane. The section on the Philippines includes a reference to the effect of fiber on the Java Ratio.

In Mauritius, cane quality is expressed in terms of the yield of 99° purity sugar per cent cane. The predicted yield of sugar is determined from the crusher juice and fiber inspections which are factored to absolute juice – and from which the yield of sugar is calculated.

Two methods of direct cane quality determination are discussed in this chapter. In the cold water extraction process, the cane sample is disintegrated and sub-sampled. Weighed portions of the sub-sample and tap water are vigorously agitated in a container which is equipped with rapidly rotating blades. The residue and extract are then analyzed to determine the sucrose, Brix, and fiber per cent cane. The Queensland Wet Disintegrator method and the South African Cold Extraction process are covered in the respective sections on Queensland and South Africa. The Pol Ratio of Hawaii is discussed in a separate section.

The other method of direct cane quality determination involves the use of the three-roll sample mill. The application of the sample mill to cane quality determination at the USDA Houma, Louisiana, Experiment Station is covered in the final section of this chapter.

It is of interest to note that the majority of the systems attempt to predict cane quality in terms of recoverable sugar in the cane rather than merely in terms of the sucrose content of the cane. Such a procedure requires the incorporation into the cane quality formula of the mill extraction and the factory retention. There is a growing trend toward establishing standards of milling and boiling house efficiency. Such standards protect the farmer from the low yields of the inefficient factory and permit the efficient factory to rapidly recover its investment in new equipment. For the proper application of milling and boiling house standards, accurate chemical control is necessary, and in many areas statutory regulations require dilute juice and maceration water measuring devices.

Many of the indirect cane quality determination methods now incorporate fiber into the evaluation. This expedient recognizes that while the crusher juice inspections are a measure of juice quality, the fiber in the cane is a measure of juice quantity and the milling response of the cane. This trend has, to a large degree, discredited the Java Ratio method which is based on crusher juice inspections only. The other side of the coin is that much more extensive laboratory control is necessary for such fiber determinations as compared to the relatively simple Java Ratio method.

There is a certain similarity in the manner in which several of the cane evaluation methods relate the farmer's cane quality to actual commercial factory performance. For such a correlation, a factor is derived, and this factor is applied to the farmer's sample inspections to determine his cane quality. The factor may be determined weekly, bi-weekly, or for the crop and may be expressed in general terms as follows:

$$\text{Factor} = \frac{\text{Factory Units}}{\text{Total Farmers' Units}}$$

For such a factor to be rigorously correct, the farmers' units (as sucrose per cent cane, sugar, etc.) should include both the independent and factory-owned cane.

Then:

$$\text{Each Farmer's Cane Quality} = \text{Each Farmer's Units} \times \text{Factor}$$

In the recent modifications to the Queensland CCS system, the farmers' units are CCS units as calculated from the CCS formula, while the factory units are CCS units as determined from the actual factory performance.

Similary, in the Reunion system, the farmers' SE are obtained from the SE formula, while the factory SE is obtained from the actual factory performance.

Like the Queensland CCS method, the Reunion SE system incorporates certain assumptions as to factory efficienty in the formula. However, the Reunion system goes a step farther and requires minimum levels of factory efficiency in determining the factory SE from actual performance.

QUEENSLAND

(The CCS and Wet Disintegrator Methods)

Social, Economic, and Legislative Systems

Queensland, with about 32 factories, accounts for about 95 per cent of the total Australian sugar production. New South Wales accounts for the remaining 5 per cent. About one half of the Australian raw sugar factories are cooperatively owned while the remaining factories are privately owned.[1]

Statutory control of the Queensland industry dates back to 1915 with the establishment of the Sugar Cane Prices Board, which was set up for the purpose of administrating cane quality evaluation and cane

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[1]Roberto Gonzales-Rivera, Informe Sobre El Viaje Australia, Hawaii, Estados Unidos de America, (Reimpreso de la XXIV Memoria Anual de la Asociation de Tecnicos Azucareros de Cuba, 1950), pp. 12-13.

payment. The current control of the industry embodies the following principles in the Regulation of Sugar Cane Prices Acts, 1915 to 1954:

1. The price of sugar is determined by the government.
2. The price of cane is fixed in relation to the price of sugar.
3. Planters are assigned by area to a particular factory and are required to supply cane only to that factory.
4. Factories are compelled to accept cane from the planters in their assigned area.

Control rests in the hands of a Central and Local Cane Prices Boards. These boards make the assignments of planters to the factories, and through awards in each area set the cane volume for the planter, the conditions dealing with the supply and delivery to the factory, sampling details, and the provisions for cane payment. The findings and awards of the boards are periodically published in the Queensland Gazette – a government publication.

"Cane Testers" at each factory – employed by the Central Board – oversee cane weighing, sampling, analysis, and the clerical work as these factors affect payment for the cane.

Sugar cane production in Queensland is essentially by small independent planters. The median size farm is about 60 acres. A few factories grow a substantial amount of administration cane, but the majority grow no cane.[2]

There are about 8000 assignments (farms) with a total area of nearly 600,000 acres. Total sugar production averages about 1,200,000 long tons annually of which about 650,000 long tons are exported and the remainder consumed locally.[3]

Cane is predominantly hand harvested. Transportation is primarily by privately owned railway systems called tramways - the cars having a nominal capacity of 2 to 3 tons. Alternative transportation is by public railway in which the cars average 6 to 12 tons. Some cane is transported by trucks (lorries) ranging in capacity from 5 to 7 tons.[4]

Sampling

Each shipment of cane is accompanied by a "truck" ticket showing name, date, field, variety, class (plant or ratoon), and whether burned or green cane.

Depending on the size of the shipment, sampling may be continuous or spot. Continuous sampling is practiced where the deliveries

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[2] Ibid., 1. 12.

[3] J. L. Clayton, "The Queensland System of Cane Payment," Proceedings of the Tenth Congress of the International Society of Sugar Cane Technologists, (1959), p. 205.

[4] Ibid., pp. 207-208.

are relatively large in size and few in number. Sampling is continuous throughout passage of the same consignment through the mill. A "sample" may constitute from 5 to 50 tons, but generally averages 15 to 35 tons. The sampling may be automatic through employment of the "Sivyer" sampler. This device is actuated as each delivery enters the carrier and performs the entire sampling operations without human assistance.[5]

Factories which receive a high frequency of small size cane deliveries use spot sampling. Here every tenth, twelfth, or fifteenth ton supplied by a planter constitutes a sample load. For tram cars this may mean that every fifth or sixth tram car is taken as a "sample", and collection of juice proceeds during the milling of the car only. Larger factories have found it necessary to consolidate several tram cars into a minimum unit for sampling.

Testing and Evaluation

The standard of cane quality in Queensland is CCS, (Commercial Cane Sugar). Technically, CCS is defined as that percentage by weight of a shipment of cane which would be recovered as pure sucrose if milling and boiling house operations were conducted at a prescribed level of efficiency. CCS thus represents a theoretical yield. The CCS formula, devised in 1888 and incorporated in the original 1915 statutory

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[5] *Ibid.*, p. 208.

regulations, in its simplest form states that the sucrose recoverable from a given quantity of cane (CCS) is less than the sucrose present in the cane by an amount equal to one half of the soluble impurities in the juice in the cane.

$$\text{CCS} = \text{Sucrose in Cane} - \frac{\text{Dissolved Impurities in Cane}}{2}$$

To make the formula adaptable to routine sampling, the quality of the first expressed juice and the fiber content of the cane are incorporated into the basic formula through factors to give the cane quality formula in its well-known form,

$$\text{CCS} = P\,(100 - (F + 5) - \frac{1}{2}\left[B\left(\frac{100 - (F + 3)}{100}\right) - P\left(\frac{100 - (F + 5)}{100}\right)\right]$$

or

$$\text{CCS} = \frac{3}{2}\;P\left[1 - \frac{F + 5}{100}\right] - \frac{1}{2}\;B\left[1 - \frac{F + 3}{100}\right]$$

where: P is the pol (apparent sucrose) % first expressed juice.

B is the Brix % first expressed juice.

F is the fiber % cane.

A close inspection of the above formula reveals that it incorporates the following theoretical assumptions:

1. Basis for the formula is the total juice in the cane (absolute juice).
2. Total juice (absolute juice) per cent cane = 100 – fiber per cent cane.
3. If the first expressed juice inspections are applied directly to the absolute juice per cent cane, higher Brix and pol per cent cane than actual (or pseudo values) are obtained. Therefore, to obtain the total Brix and pol in the cane, three per cent and five per cent of the Brix and pol in the first expressed juice are subtracted from the pseudo Brix and pol in the cane.
4. Sucrose losses in bagasse (milling losses) and in mud are nil.
5. Every pound of soluble non-sugars in cane carries with it into final molasses one-half pound of sucrose.

<u>The Front Roller Juice – Stick Fiber CCS</u> – For many years the front roller juice – stick fiber CCS system has been used for cane quality assessment. The juice sample, as the name implies, is taken from a two roll crusher or from the front roll of a three roll crusher. Appropriate fiber contents are applied to the CCS formula. These fiber values represent the

specific variety, class, and condition of the cane. The fiber values have been determined previously from direct fiber determinations on stalks of cane which have been removed from "sample" cars and segregated according to variety, whether plant or ratoon, and whether burned or green.[6] In its simplest application, only two fiber figures are used, i.e., "hard" cane and "soft" cane.

The CCS so determined is applied directly to the Board Award Cane Price Scale.

The Individual Fiber and Juice Weight CCS — With the advent of juice scales and the subsequent more precise chemical control, inadequacies began to appear in the Front Roller – Stick Fiber CCS method. Particularly evident were discrepancies between undetermined losses by the juice scales and those based on the CCS method currently in use. This trend was aggravated by mechanization of harvesting operations in some areas and delay between burning and milling of cane.[7]

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[6] E. R. Behne, "The C.C.S. Formula," Cane Growers Quarterly Bulletin, (April, 1948).

[7] G. A. Anderson, "The Juice Scales – Individual Fiber System for the Determination of Cane Quality," Proceedings of the Tenth Congress of the International Society of Sugar Cane Technologists, (1959), p. 182.

Changes in the CCS method were permitted by an amendment to Regulation 51. This amendment incorporated revisions in the method of determining fiber and permitted the juice scales to be used as control to determine a corrected CCS.

Under the amended system, weekly fiber determinations are made for the individual planters. For this, random samples of cane are removed from the carrier after knifing and shredding, and the fiber content is determined. The average fiber for each planter from three consecutive weeks' determination is incorporated into the planter's CCS formula along with the front roll juice analysis from each cane delivery.

In addition, a weekly factory CCS is determined, which is based on the measurement of the cane, maceration water, and mixed juice. The factory CCS retains the concept that the pure recoverable sucrose is equal to pol in cane minus half the soluble impurities. However, instead of using factors, the pol and Brix are obtained from the factory control measurements and calculations.[8]

At weekly intervals the average planters' CCS is determined from the CCS for each planter by the CCS formula. This

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[8] *Ibid.*, pp. 209-210.

CCS is compared with the average factory CCS. The ratio of the two thus constitutes a correlation factor:

$$\text{Correlation Factor} = \frac{\text{Weekly Average Factory CCS}}{\text{Weekly Average Planter CCS}}$$

A factored CCS for each planter is then obtained by applying the correlation factor to his CCS determination for the week.[9]

Direct Analysis of Cane by The Wet Disintegrator Method

As an alternative to the CCS method of cane evaluation, the Bureau of Sugar Experiment Stations has undertaken a study devoted to direct analysis of mill feed. "The "wet disintegrator," which has developed from these studies, consists of a vertical shaft rotating at 6000 rpm in a container 13 inches high and 11 inches in diamter. The shaft carries three spring steel blades 5 inches long and spaced 1/2 inches apart. The blades are set at the end of the shaft almost at the bottom of the container.

A tentative method of operation includes sampling and compositing the sample of cane to the first mill of the tandem. The composited cane is mixed, quartered and sub-samples to approximately 4 kg. From this sub-sample, a 2 kg. portion is taken for pol and Brix

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[9]Clayton, op. cit., p. 210.

analyses with the disintegrator, and the remainder is used for moisture determination. The 2 kg. sample and 8 kg. of water are placed in a disintegrator and pulped for 30 minutes. Brix of the extract is determined by pycnometer and pol by Horne's dry lead.

Moisture is determined by drying a hammer-milled sample for three hours at 105°C. in a Spencer Oven.

Pol and Brix per cent Cane are calculated by formulas which incorporate the Brix and pol inspections of the extract, the moisture per cent cane and assumptions on the hygroscopic moisture contained in the cane.[10]

Tentative observations of direct cane evaluation by the Wet Disintegrator method operated in parallel with juice weight control indicate that the results of the direct evaluation do not agree with those based on juice weight control. This suggests a possible fundamental difference between the effects of milling on one hand and of pulping on the other.[11]

Anderson cites some practical disadvantages to the direct method of cane evaluation:[12]

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[10]R. Diecke, "Investigations with the Wet Disintegrator for the Direct Analysis of Cane," Proceedings of the Tenth Congress of the International Society of Sugar Cane Technologists, (1959), pp. 169-173.

[11]Clayton, op. cit., p. 211.

[12]Anderson, op. cit., p. 185.

1. With the Wet Disintegrator method, a considerable increase in the laboratory staff will be necessary.

2. Routine pycnometer Brix determinations will require a higher degree of skill on the part of the laboratory staff than at present.

Miscellaneous Comments

The general problem of rapidly changing conditions in the industry on a cane payment system has been well expressed by Clayton:

> "For many years Queensland has enjoyed a sampling system which was compatible with the operation of harvesting and transport of the cane; a quality formula which, though not perfect, gave a high degree of satisfaction; and a payment formula based on sound principles.
>
> "Events have conspired to upset the smooth working of this machinery. The industry has expanded considerably since 1950 and crushing rates have soared, but the unit delivery of cane remains about the same. Both the size of the average farm and the number of farms have risen substantially. The need for streamlining the handling of cane is more pressing and the burden of the sampling system is becoming more onerous. Mechanical harvesting is on the horizon and might well have made more rapid strides in the industry but for the fact that under many circumstances it would call for substantial modification of the present payment system."[13]

Effect of Wash Water on CCS — A 1956 Circular of the Queensland Cane Growers' Council, in discussing the problem of field soil in the cane

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[13] Clayton, op. cit., p. 211.

entering the tandem, suggested the application of a CCS correlation factor to compensate for wash water applied to cane in the carrier. With such an approach, all cane would have to be washed to provide a constancy of factors.[14]

Effect of Dirt on Cane Weight and Juice Brix - Anderson discusses studies on the effect of suspended soil and other insoluble solids - collectively referred to as dirt. Dirt in this case was determined by centrifuging juice samples and drying the deposit. Dirt amounted to 0.5 per cent of mixed juice in 1957 and 0.66 per cent in 1958. By making Brix inspections on centrifuged and uncentrifuged juice samples, it was found that the Brix inflation due to dirt was 0.21 units in 1957 and 0.34 units in 1958. This corresponded to 0.7 per cent and 1.1 per cent CCS respectively.[15]

REUNION[16]
(The SE Method)

Social, Economic, and Legislative Systems

Fourteen factories on the Island produce about 175,000 tons of

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[14]Queensland Cane Growers' Council, Circular No. "D" 6, (March 29, 1956), p. 3.

[15]Anderson, op. cit., p. 184.

[16]E. Hugot, "Cane Payment on a Quality Basis, An Extractable Sugar Formula in Reunion," The International Sugar Journal, LVII (1955), pp. 187-190.

raw sugar annually.

The industry is subject to legislative control through the Centre Technique de la Canne et du Sucre, a branch of the Department of Agriculture. Chemists of the Centre Technique are placed at each factory during the grinding season.

About two-thirds of the Island cane is grown by independent planters while the remaining one-third is cultivated on estates owned or leased by the factories.

For purposes of administering cane receipts, three categories of cane supply are recognized, i.e., large growers producing over 2,000 tons of cane per season (and whose cane deliveries are analyzed separately); groups of two or several growers joined together to reach 2,000 tons; and regions made up of small growers. The inspections of cane delivered by groups and regions are applicable to all growers in the group or region.

Cane is normally delivered by trucks, and one truckload constitutes a "determination" or basis for sample. Small growers deliver by ox-cart, and 4 to 5 cartloads are necessary to make a "determination".

Sampling

Cane in the carrier is marked with lime to indicate the beginning and end of a delivery for sampling. Sampling is continuous while the truckload or cart-combination passes through the crusher.

A crusher juice sample is collected from each "determination". The fiber inspections are made less frequently — one for every two or three juice analyses.

Testing and Evaluation

The standard of cane quality in Reunion is SE (Extractable Sugar). SE is defined as the commercial raw sugar of 97° titre per cent cane that should be obtained from a cane delivery by a factory of 95 per cent extraction and 100 boiling house efficiency.[17] SE thus represents a theoretical yield.

The Reunion cane quality formula which was developed by E. Hugot, is expressed as follows:

$$SE = K \times B_1 \frac{(P_1 - 30)}{100} (1 - 1.4f)$$

where: SE is commercial sugar of 97° titre, % cane.

B_1 is the Brix of the first expressed juice.[18]

P_1 is the apparent purity of the first expressed juice.

f is the parts of fiber per 100 parts of cane.

K is the factory Efficiency Coefficient.

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[17] Titre = sucrose - 2 x glucose - 4 x ash.

[18] Crusher juice inspections include Brix by hydrometer and apparent sucrose (pol). While the term sucrose is used for simplicity throughout the discussion of the formula, the author notes that this is the apparent value, i.e., the pol.

Basis for the SE formula

1. The formula is developed from the absolute juice in the cane. The absolute juice quality is inferred from the crusher juice inspections and the fiber content of the cane. Fairly fixed ratios of the first expressed juice and absolute juice Brix and purity are assumed. Thus S, the sucrose per cent cane has the form:

$$S = B_o \frac{P_o}{100} (1 - f)$$

or

$$S = K_1 B_1 \frac{P_1}{100} (1 - f)$$

where: S is the sucrose % cane.

B_o is the Brix of the absolute juice.

P_o is the purity of the absolute juice.

B_1 is the Brix of the first expressed juice.

P_1 is the purity of the first expressed juice.

K_1 is a combined coefficient relating the first expressed juice Brix to the absolute juice Brix and the first expressed juice purity to the absolute juice purity.

2. The above formula for sucrose per cent cane is adjusted to account for a standard extraction and losses in muds

and undetermined losses. The standard extraction is a 95 per cent reduced extraction at 12.5 per cent fiber in cane. Losses in muds and undetermined losses are accounted for by a factor K_2. Hence the sucrose per cent cane, E, obtained after a standard extraction and after accounting for undetermined losses and losses in muds is:

$$E = K_1 K_2 B_1 \frac{P_1}{100} (1 - f)(1 - 0.4f)$$

3. The standard retention is developed through the use of the SJM formula and a boiling house efficiency of 100. Essentially, the mixed juice purity is factored from the first expressed juice purity, P_1, through a factor K_3 and assuming a final molasses purity of about 29. Sugar of 100 purity is assumed. These adjustments give the basic formula:[19]

$$SE = K_1 K_2 K_3 B_1 (1 - 1.4f) \left(\frac{P_1 - 30}{100}\right)$$

or

$$SE = K B_1 (1 - 1.4f) \left(\frac{P_1 - 30}{100}\right)$$

[19] While not mentioned in the article, it appears that K_3 must also account for factoring the yield from pure sucrose per cent cane to commercial sugar per cent cane.

<u>Application of the SE Formula</u> – The determination of the SE for each grower, group, or region, involves the following steps:

1. A crop average Cane Coefficient of Quality Z_r, is determined for each grower, group, or region.

$$Z_r = B_1 \left(\frac{P_1 - 30}{100} \right) (1 - 1.4f)$$

2. The weighted average Coefficient of Quality, Z_m, is determined for all deliveries by multiplying Z_r times the tons of cane delivered by each grower, group, or region, T, and summing the products for Sum Z_r x T. This sum is divided by the total tons of cane delivered to the factory, T total.

$$Z_m = \frac{\text{Sum } Z_r \times T}{T \text{ total}}$$

3. The factory Efficiency Coefficient, K, is determined by dividing the <u>actual</u> factory yield of 97° commercial sugar per cent cane, R_m, by the weighted average coefficient of Quality, Z_m.

$$K = \frac{R_m}{Z_m}$$

4. The SE for each grower is then determined by multiplying the grower's Cane Coefficient of Quality, Z_r, by the factory Efficiency Coefficient, K.

$$SE_{(grower)} = K\,Z_r$$

However:

a. The Efficiency Coefficient is to be not less than 1.20 nor greater than 1.30.

b. If the Efficiency Coefficient for any one year is greater or less than that of the previous year by 0.005, the payment will be made on $K + 0.005$ or $K - 0.005$.

The purpose of these provisions is to protect the grower from an inefficient factory by setting a ground level of factory efficiency, and to permit the efficient factory to rapidly recover its investment for new equipment by setting a ceiling to the Coefficient.

In addition, in calculating the Efficiency Coefficient, a minimum yield per cent cane, R_m, is required for each factory. The minimum is 10.00 for the Windward region and 10.50 for the Leeward region.

Miscellaneous Comments

Of interest are the provisions made for an initial gradual application of the new formula. Until 1953, cane payment was on a flat weight basis and there was no cane quality evaluation. The new system was instituted in 1954. However, at that time there was considerable variation between factory efficiencies, and had an Island average factory Efficiency Coefficient been applied to the growers' Cane Coefficient of Quality, some up-to-date factories would have made abnormal profits, while others would have been severely penalized. Hence a transition period of five years was chosen. During this period the grower was not paid for his full SE of $K Z_r$. A phased system was introduced, gradually leading up to the full payment by the fifth year.

SOUTH AFRICA

(The Java Ratio and Cold Extraction Methods)

Legislative System

The South African industry operates under the Sugar Industry Agreement of 1943 as amended. Control under the Agreement rests in the Sugar Industry Control Board which consists of three members, i.e., a grower and a factory representative and a third member nominated by the Sugar Association. Subject to control under the Agreement are growers' quotas, mill assignments of growers' quotas, the price of sugar and the price paid for sugar cane. Awards and findings of the Board are published in the government Gazette.

When desired by the growers delivering to a factory, a "technical manager," who is in charge of cane testing and who is employed by the Board, is maintained at the factory.

Sampling

Crusher juice samples are collected representing 80 per cent of cane shipments of 15 tons and over, and 60 per cent of shipments between 10 and 15 tons. Every attempt is made to sample consignments under 10 tons.[20]

Testing and Evaluation[21]

The inspections of the first expressed juice include pol by Horne's dry lead while undiluted juice sucrose is by the Clerget method.

The Java Ratio is used in South Africa where the standard of cane quality is sucrose per cent cane. Samples of crusher juice from the consignments of cane are tested for apparent sucrose (pol) and the results are applied to the cane quality formula as follows:

$$\text{Sucrose \% Cane} = \text{Pol \% Crusher Juice} \times \text{Java Ratio}$$

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[20] *Sugar Industry Agreement, 1943, As Amended* (October 15, 1952), Schedule C, Par. 13.

[21] K. Douwes Dekker, "The Determination of Certain Qualities of Individual Consignments of Sugar Cent," *Proceedings of the Ninth Congress of the International Society of Sugar Cane Technologists*, II, (1956), pp. 722-723.

The Java Ratio is determined weekly by the factory and is calculated by dividing the weight of sucrose in cane milled during the week by a pseudo weight of sucrose in the crusher juice:

$$\text{Java Ratio} = \frac{\text{Weight of Sucrose in Cane}}{\text{Weight of Sucrose in Crusher Juice}}$$

The pseudo weight of sucrose in crusher juice is determined by multiplying the weight of each cane consignment by the crusher juice sucrose for the consignment. The weight of sucrose in cane is determined from the factory control records as the sum of the weight of sucrose in undiluted juice and in bagasse. To ensure accuracy of factory control, weighing scales for juice and scales or meters for maceration water are required.

Direct Analysis of Cane by Cold Extraction

Studies were initiated in 1934, covering the direct evaluation of sucrose in cane samples.[22] These studies culminated in the development of the Cold Extraction process using an extractor equipped with one or two rapidly rotating sets of knives.

In the process, 100 to 150 pounds of cane are disintegrated in a chaff cutter, the chips are mixed in a mixing barrel, and a 10 pound sub-sample is removed. The sub-sample is fibrated in a Waddell

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[22]K. Douwes Dekker, "A Survey of the Work Done in S.A. on the Direct Analysis of Cane Consigments," Sugar Milling Research Institute, Quarterly Bulletin No. 7, (August, 1958), pp. 23-25.

shredder and a 600 gm. sample is removed and charged to the extractor. 1500 gm. of water are then added, and the mixture is agitated for 20 minutes. The extract is analyzed for apparent sucrose (pol) and the residue for fiber.

The Cold Extraction process and the method of sampling have shown good reproducibility. In parallel tests on the same charge, the mean coefficients of variation for pol and fiber were 1.48 and 1.46 respectively.

Subsequently, the Cold Extraction process was operated in parallel with the mill control at Umfolozi factory in 1957. The direct analysis method showed an average of 1.8 per cent higher pol than that by the mill control. In view of the relatively small error, it was concluded that the Cold Extraction process was promising as a method of direct cane evaluation.[23]

Further work - directed to developing an automatic cane sampler - resulted in a rotary kicker device to work on the knifed cane just prior to falling into the crusher.

Studies of the Cold Extraction process were expanded to include investigations on Brix-free water (W) - the water bound to cane fiber by physico-chemical bonds.[24] Such bound water is not removed by

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[23]No data were given indicating the percentage of total mill feed which was sampled.

[24]Dekker, "A Survey --," op. cit., p. 25.

mill pressure – only through drying the fiber at elevated temperatures. These investigations indicated that the Brix-free water for the average fiber is about 30 per cent dry fiber.

A correct definition of fiber was proposed as "cold water insoluble material in cane." Thus defining fiber, the determination of juice per cent cane then becomes:[25]

$$\text{Juice Per Cent Cane} = 100 - 1.3\,F$$

where:

F is dry fiber per cent cane.

The calculations for sucrose in the extract from the wet extractor include a correction for the Brix-free water.

The standard method of determining the fiber content of the cane with the Cold Extraction process involves drying the residue remaining after the extraction. An extensive study to determine more rapid methods of fiber determination was unsuccessful in that the alternative methods, if accurate, were just as time consuming as the standard method; or if rapid, lacked accuracy.[26]

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[25] Juice expressed in this manner is in contrast to the well-known interpretation of absolute juice:

$$\text{Absolute Juice \% Cane} = 100 - F$$

where absolute juice is all dissolved solids plus water in cane.

[26] C. van der Pol and C. M. Young, "Determination of Certain Qualities of Individual Cane Consignments," Sugar Milling Research Institute, Quarterly Bulletin No. 5, (January, 1958), pp. 9-13.

Miscellaneous Comments

In discussing the use of Java Ratio for cane evaluation, Douwes Dekker notes that the factory average Java Ratio is not necessarily that of the particular consignment of cane - due to the sensitivity of the Java Ratio to the fiber content of the cane.[27] In subsequent work, however, he acknowledges the advantages of the Java Ratio method which include ease of sampling the first expressed juice and the simplicity of the subsequent pol determination.[28]

JAMAICA[29]

(The Java Ratio)

Social, Economic, and Legislative Systems

About 400,000 long tons of raw sugar are annually produced by 20 privately owned factories, which range in capacity from 5,000 to 85,000 tons of raw sugar.

Approximately 46 per cent of the total Island cane production is cultivated by independent cane farmers. The remaining cane is grown by factory estates. Volume of production of the independent cane

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[27] Douwes Dekker, "The Determination---," op.cit., p. 732.

[28] Douwes Dekker, "A Survey---," op. cit., p. 25.

[29] The material in this section is based on discussions with representatives of the Jamaica Sugar Industry.

farmers varies widely from the small operator who produces less than five tons of cane annually, to the large farms producing above 1000 tons of cane.

Statutory regulation of the Island industry is under the provisions of the Sugar Industry Control Law of 1937 as amended. The law controls the manufacture of sugar through factory quotas and export licenses and the production of sugar cane through registration of – and cane assignments to – the independent growers.

Compared with other cane growing areas in the world, legislative control – as it affects the relations of the factories to the independent cane farmers -- is nominal. Substantially, (1), cane prices, (2) regulations regarding sampling, testing and evaluation of cane, and (3) matters of dispute between the independent farmer and the factory are controlled through agreements between the All Island Jamaica Cane Farmers' Association (CFA), representing the independent cane farmers, and the Sugar Manufacturers' Association (SMA) representing the factories.

Cane testers are employed by the cane farmers to observe the cane sampling and testing procedures as they affect the evaluation of the independent farmers' cane.

To facilitate cane delivery and evaluation, the small farmers are grouped together by region, and the sample and test results of cane delivered by such a regional group apply to all farmers in the group.

Cane is delivered to the factories by truck, ox-cart, and rail.

Sampling

Crusher juice samples are analyzed for hydrometer Brix, apparent sucrose (pol), and purity.

Individual tests are provided for farmers whose annual cane deliveries total 500 tons or more. The frequency of sampling for individual farmers and for regional groups is established at a minimum of 10 per cent of each week's cane delivery.

Testing and Evaluation

The <u>standard of cane quality</u> is Tons of Cane per Ton of 96^{o} Sugar, TC/TS. The cane quality formula is: $\left[\frac{TC}{TS}\right]_{\text{Farmer}} =$

$$\frac{\left[\text{Pol \% Crusher Juice} \times \text{W. C. Retention @ Crusher Juice Purity}\right]_{\text{Factory}}}{\left[\text{Pol \% Crusher Juice} \times \text{W. C. Retention @ Crusher Juice Purity}\right]_{\text{Farmer}}} \times \left[\frac{TC}{TS}\right]_{\text{Factory}}$$

where: W. C. Retention is the theoretical retention as determined from the Winter-Carp formula.

The farmers' data are determined from his weighted average crusher juice inspections for the crop.

The factory TC/TS is determined from the average factory performance for the crop:

$$\frac{TC}{TS}\ \text{Factory} = \frac{1}{Y}$$

and

$$Y = S \times JR \times E \times R_{Theo.} \times BHE \times K$$

where: Y is the yield of 96° sugar per ton of cane.

S is the Pol % crusher juice.

JR is the Java Ratio, $\frac{\text{Pol \% Cane}}{\text{Pol \% Crusher Juice}}$.

E is the actual mill pol extraction.

R_{Theo} is the Winter-Carp theoretical retention.

BHE is the actual boiling house efficiency.

K is the factor for conversion of Pol in sugar – at the actual purity of sugar – to 96° test sugar, as shown in Table 39, page 764, of the Cane Sugar Handbook, (8th Edition), by G. L. Spencer and G. P. Mead.

Dimensionally, the basic formula for yield (Y) may be expressed as follows:

$$96^{\circ}\ \text{Sugar} = \frac{(\text{Pol})_{C.J.}}{\text{Cane}} \times \frac{(\text{Pol})_{\text{Cane}}}{(\text{Pol})_{C.J.}} \times \frac{(\text{Pol})_{M.J.}}{(\text{P0l})_{\text{Cane}}} \times \frac{(\text{Pol})_{\text{100 Purity Sugar}}}{(\text{Pol})_{M.J.}} \times$$

$$\frac{(\text{Pol})_{\text{Actual Purity Sugar}}}{(\text{Pol})_{\text{100 Purity Sugar}}} \times \frac{96^{\circ}\ \text{Sugar}}{(\text{Pol})_{\text{Actual Purity Sugar}}}$$

PHILIPPINES[30]

(The Java Ratio and Effect of Fiber)

General

Crusher juice inspections include Brix by hydrometer and apparent sucrose (pol) by dry lead.

The standard of cane quality is Piculs of Sugar per Ton of Cane. (A picul is about 133-1/2 pounds). The cane quality formula is:

$$\frac{\text{Piculs of Sugar}}{\text{Tons of Cane}} = \text{Pol \% Crusher Juice} \times \text{Factor}$$

$$\text{where Factor} = \frac{\text{Piculs of Sugar}}{(\text{Ton Cane})\ (\text{Unit Pol \% Crusher Juice})}$$

The Factor is expressed as follows:

$$\text{Factor} = JR \times E \times \frac{S\ (J-M)}{J\ (S-M)} \times BHE \times \frac{1}{PS}$$

where: JR is the Java Ratio, $\frac{\text{Pol \% Cane}}{\text{Pol \% Crusher Juice}}$.

E is the pol extraction.

J is the apparent purity of the mixed juice.

M is the gravity purity of the molasses.

S is the gravity purity of the sugar.

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[30] The material in this section is based on correspondence with representatives of the Philippine sugar industry.

BHE is the boiling house efficiency.

PS is the polarization of the sugar.

Dimensionally, the Factor analyzes as follows:

$$\frac{\text{Comm. Sugar}}{(\text{Pol})_{\text{C.J.}}} = \frac{(\text{Pol})_{\text{Cane}}}{(\text{Pol})_{\text{C.J.}}} \times \frac{(\text{Pol})_{\text{M.J.}}}{(\text{Pol})_{\text{Cane}}} \times \frac{(\text{Pol})_{\text{Theo.Ret.}}}{(\text{Pol})_{\text{M.J.}}} \times \frac{(\text{Pol})_{\text{Act.Ret.}}}{(\text{Pol})_{\text{Theo.Ret.}}} \times \frac{\text{Comm. Sugar}}{(\text{Pol})_{\text{Act.Ret.}}}$$

Tables of Factors are worked out to express the yield for corresponding crusher juice purities. Some factories use specific standards of mill extraction and boiling house retention in these Factors. In this manner, the farmer's cane quality is independent of the factory efficiency.

The Effect of Fiber on the Java Ratio[31]

Use of the Java Ratio to evaluate, through crusher juice analysis, the sucrose content or the commercial sugar in a cane shipment, assumes a constancy of the Java Ratio. In the first place, this presupposes that the Java Ratio is constant for any given milling equipment

[31] Manuel V. Locsin, "Influence of Fiber on Java Ratio," Proceedings of the Philippines Sugar Technologists, (1953), pp. 134-139.

and under any given set of milling conditions. More important, it is assumed that the Java Ratio remains constant irrespective of the fiber in the cane.

Studies in Hawaii and South Africa have shown a definite dependence of the Java Ratio on the fiber content of the cane.

Studies conducted at the Victorias Milling Company in the Philippines, of the mean Java Ratio and the per cent fiber from seven replicate samples of each of five varieties, showed a clear tendency of the Java Ratio to decrease with increasing fiber in cane. The varieties with high fiber had correspondingly low Java Ratios.

The number of replicate tests performed on each variety was insufficient to obtain a dependable correlation between Java Ratio and fiber per cent cane for each variety.

MAURITIUS[32]

General

During a 100 day crop period, 30 factories produce about 445,000 tons of sugar. Since 1940, cane payment has been on a quality basis. Cane evaluation and payment are governed by the Sales of Cane (Control) Ordinance No. 47 of 1941. Statutory control of the industry

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[32] J. D. De R. Saint Antoine, "Cane Payment in Mauritius," Proceedings of the Tenth Congress of the International Society of Sugar Cane Technologists, (1959), pp. 163-167.

under the Ordinance is vested in the "Central Arbitration and Control Board." Each factory is assigned a factory area from which it receives all its cane, and all cane grown within the area must be processed at the area factory. Each factory is required to have automatic scales for weighing juice and maceration water. These scales are periodically checked by officers of the Board.

Sampling

Cane is hand harvested. Delivery to the factories is chiefly by rail, although some cane is conveyed by truck.

Crusher juice samples of the cane consignments from the independent planters are analyzed for Brix and purity. Direct fiber determinations are made concurrently on the cane in the carrier. For this purpose about 90 stalks are selected, mixed, and sub-sampled. The sub-samples are cut into three equal portions and shredded in a Queensland fibrator (Cutex). A portion of the disintegrated cane is collected in a cloth, washed for 24 hours in cold running water, and dried at 100°C.

The frequency of sampling – based on the total cane delivered by the independent planters – is about 10 per cent. The amount of cane acceptable for a test is that equivalent to a minimum of ten minutes grinding. Farmers whose participation is too small for individual cane tests are grouped together – usually on a regional basis – for purposes of sampling.

Testing and Evaluation

The standard of cane quality is commercial sugar of 99 purity per cent cane. The cane quality formula relates the planter's "true" sucrose per cent cane to his yield through a standard reduced extraction based on his fiber per cent cane and a standard retention based on his mixed juice purity. (Crusher juice inspections include pol – or apparent sucrose, and mixed juice inspections include sucrose by the Clerget method.)

$$\text{Yield, 99 Purity Comm. Sugar \% Cane} = \text{"True" Sucrose \% Cane} \times \text{Standard Reduced Extraction} \times \text{Standard Retention} \times \frac{1}{98.5}$$

As applied in actual practice, the planter's inspections are first factored to the mill inspections during the test period in which he delivered his cane (planter's "arbitrary" sucrose to "true" sucrose per cent cane) and then factored again to reflect the difference between the average factory inspections during the test period and the crop (planter's fiber and calculated mixed juice purity during the test period corrected to a crop basis). The fact that many planters do not deliver over the whole crop is cited as the reason for correcting their inspections to a crop basis.

The method of evaluation involves the following principles, steps, and assumptions:

1. Determination of an "arbitrary" planter and mill sucrose per cent cane during the test period in which the cane was delivered. (For the mill, this is the run during which the planter's cane was delivered.)

   a. The "arbitrary" sucrose per cent cane is based on the absolute juice content of the cane as follows:

$$\text{"Arbitrary" Sucrose \% Cane} = \frac{B_A \times P_A \times \text{A.J. \% Cane}}{10,000}$$

where: B_A is the Brix of the absolute juice.

P_A is the purity of the absolute juice.

A.J. % Cane is the absolute juice % cane which is equal to 100 − fiber % Cane.

   b. The relationship between the quality of the first expressed juice and the absolute juice assumes:

      (1) A linear relationship between the Brix of the first expressed juice and the absolute juice:

$$B_A = 0.89\ B_1 + 1.3$$

where: B_1 is the Brix of the first expressed juice.

(2) A difference between mill first expressed juice and absolute juice purities for the run which is constant for all cane processed during the run. This difference is applied to the planter's first expressed juice purity to determine his absolute juice purity. Thus the planter's absolute juice purity for the test period is:

$$P_{AP} = P_{1P} - (P_{1M} - P_{AM})$$

where: P_{AP} is the calculated absolute juice purity of the planter's sample.

P_{1P} is the first expressed juice purity of the planter's sample.

P_{1M} is the average first expressed juice purity of all cane delivered to the mill during the test period.

P_{AM} is the absolute juice purity from the mill control records and represents all cane delivered during the test period.

2. Calculation of a "true" sucrose per cent cane from the "arbitrary" sucrose of the planter and of the mill during the test period.

a. The difference is determined between the "arbitrary" sucrose for the planter's cane which is ground during the test period and the mill "arbitrary" sucrose for the same period.

b. The mill "true" sucrose is then determined from the factory control data.

c. The planter's "true" sucrose is finally determined by adding to the mill "true" sucrose the difference between the "arbitrary" sucrose for the planter and the mill.

3. Determination of the planter's yield of 99 purity sugar at the end of the crop by means of the cane quality formula in which – to his "true" sucrose per cent cane – are applied a standard mill extraction – corrected for the fiber in the planter's cane – and a standard retention – calculated for the planter's mixed juice purity.

   a. The standard mill extraction is the reduced sucrose extraction of 95.0 sucrose per cent sucrose in cane at 12.5 fiber per cent cane.

      (1) The extraction is determined from the planter's fiber which is corrected to a crop basis by applying to his fiber per cent cane for the test period the difference between the mill fiber per

cent cane for the crop and the test period.

b. The standard retention is based on the SJM formula assuming a commercial sugar purity of 99.0, a Clerget gravity molasses purity of 40.0 (10 to 1 dilution), and a boiling house efficiency of 99.0.

(1) The standard retention is determined from the planter's calculated mixed juice purity which is corrected to a crop basis.

(a) The planter's mixed juice purity is first determined for the test period by deducting from his first expressed juice purity the difference between the mill first expressed juice and mixed juice purities for the test period.

(b) The planter's mixed juice purity is corrected to the crop basis from the test period basis by applying to his mixed juice purity for the test period the difference between the mill first expressed juice purities for the test periods and the crop average.

HAWAII

(Direct Quality Determination by Pol Ratio)

General

The Pol Ratio method of cane quality determination, which was developed by the Hawaiian Sugar Planters Association Experiment Station, involves the direct determination of pol per cent cane and expresses cane quality as Tons of Cane per Ton of Pol (Pol Ratio).

This method of cane evaluation, which is a cold water extraction process, has proved particularly valuable in studies of plant breeding (sugar yield per acre), estimation of losses caused by different harvesting practices, and the evaluation of cane entering factories which wash the cane at laundering stations preceding the tandem or on the carrier itself - thus making evaluation of the cane in the carrier impractical.

Since the direct method of cane evaluation entails the problem of getting representative samples in addition to processing the sample, the Hawaiian studies have included means for withdrawing a cane sample. Such expedients under study have included hand grab, mechanical grab, and the use of a machine driven cylindrical toothed coring device which withdraws a cane sample directly from the vehicle conveying the sample. Studies of the coring device have not been published generally, but it is understood that this method is quite promising.

Procedure for the Pol Ratio Method

The procedure for the Pol Ratio method involves collecting a sample, reduction and sub-sampling of the sample, extraction of the sub-sample in a disintegrator or extractor, and subsequent inspections of the extract and the pulp residue.

Depending on the source of the sample and the method of withdrawing the sample, a sample from 30 to 400 pounds may be removed. (Sampling rates may range from 0.03 to 0.40 per cent of the cane to be sampled). The sample is fed to an ensilage cutter which is so designed that approximately 15 per cent of the effluent chipped cane is diverted into a sample receiver. The diverted cane is further mixed by hand and a two pound sub-sample of chipped cane removed.[33]

The chipped cane is fed to an HSPA Disintegrator. This device consists essentially of two rotating blades in the ends of a stainless steel cylinder of approximately one gallon capacity. About twice the weight of the cane in water is added and the mixture is subjected to rapid rotation of the blades for 10 minutes. The extract is withdrawn and analyzed for Brix by the precision Abbe refractometer and for pol by the Horne's dry lead method. The pulp residue is washed, pressed, and dried to constant

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[33] J. G. Darroch, F. C. Dennison, L. J. Rhodes, "The Application of the Pol Ratio Method of Cane Analysis," Proceedings of the Tenth Congress of the International Society of Sugar Cane Technologists, (1959), pp. 199-205.

weight to give weight of dry fiber. The weight of the sample plus added water less the weight of dry fiber equals the weight of extract – from the analysis of which the weight of pol in extract is calculated and subsequently the pol per cent cane. The Pol Ratio is the reciprocal of the pol per cent cane.[34]

Reproducibility of the Pol Ratio method has been very satisfactory – a 2.3 per cent Coefficient of Variation between duplicate tests has been obtained. This is considerably less than the variation existing between plots.[35]

Comments on the Pol Ratio Method

In comparing direct cane evaluation by the HSPA Pol Ratio method with the Queensland Wet Disintegrator and the South African Cold Extraction processes, it is interesting to note several simplifications in the HSPA procedure. The concept of Brix-free water (W) is not included in the HSPA calculations, the extract being the weight of the sample plus added water less the weight of the dry fiber. The other two techniques incorporate Brix-free water so that the weight of extract is determined by subtracting from the weight of the sample plus added water the product of the dry fiber times 1.30.

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[34]John H. Payne and Henry J. Mahon, "The Pol Ratio Method for Evaluating Cane Quality," Proceedings of the Ninth Congress of the International Society of Sugar Cane Technologists, Vol. II, (1956), pp. 440-441.

[35]Ibid., p. 444.

In addition, the HSPA technique uses the Abbe precision refractometer, while the Queensland method uses the pycnometer. While the precision refractometer is more expensive than its counterpart, which is used for routine laboratory determinations, the instrument should allow considerably more rapid evaluation than the pycnometer.

Apparently, coring as a cane sampling technique has been evaluated only by the HSPA and in studies at Louisiana State University. The results of the HSPA studies, when released, should be of interest in comparison with the 1958 studies at Louisiana State University. The latter studies are discussed in a subsequent chapter.

SPECIAL STUDIES IN LOUISIANA

(The Three-Roll Sample Mill and the Sx - By Formula)

For many years the three-roll sample mill has been used in agronomic research at the Houma, Louisiana, Experiment Station of the United States Department of Agriculture. For these studies the formula $Y = Sx - By$ was developed. This formula expresses cane quality in terms of the available 96° sugar per ton of cane (Y), as determined from the sample mill juice pol (S) and Brix (B), and factors (x) and (y) - factors which relate the quality of the first expressed juice to that of the normal juice and incorporate the effect of normal juice extraction and an assumed boiling house efficiency.

The formula was developed in recognition of the fact that the true criterion of cane quality is the recoverable sugar in the cane, and not the quality of the cane, per se, and that primary juice analyses alone, are not sufficient for such quality evaluation studies.

Normal Juice is the juice extracted from sugar cane by a mill tandem when no maceration water is used, i.e., undiluted juice.

Reduction factors relating the primary to the normal juice inspections are defined as follows:

$$\text{Brix Reduction Factor} = \frac{\text{Normal Juice Brix}}{\text{Primary Juice Brix}}$$

$$\text{Sucrose Reduction Factor} = \frac{\text{Normal Juice Pol}}{\text{Primary Juice Pol}}$$

Routine evaluation of cane quality involves merely determination of the Brix and pol of the juice from a single milling in a three-roll sample mill. The juice inspections are translated into cane quality through the Sx – By formula, the factors x and y having been previously determined for the specific variety of cane through varietal milling studies.

Periodic varietal milling studies are made simultaneously on the variety under study and a standard variety grown under highly comparable conditions. In these studies, commercial milling conditions are simulated. 10 to 15 such determinations are required to accurately define the factors. The factors thus determined relate the varietal milling of the variety under study and of a standard variety.

Basis of the Formula

The Sx - By formula was developed from conventional extraction calculations and assuming the Winter-Carp theoretical retention.[36] The development of the formula is summarized as follows:

$$Y = 2000 \times N.J. \times S \times \left(1.4 - \frac{40}{P}\right) \times BHE \times \frac{1}{96}$$

or:

$$Y = 2000 \times N.J. \times S \times \frac{[1.00S - 0.40(B - S)]}{S} \times BHE \times \frac{1}{96}$$

where: Y is lbs. of 96° sugar per ton of cane.

N.J. is parts of normal juice per part of cane.

S is parts pol in normal juice per part of normal juice.

BHE is the boiling house efficiency.

P is the purity of the normal juice.

Through the use of the reduction factors relating the primary juice to the normal juice inspections, a normal juice/cane ratio of 1.00, and a BHE of 1.00, the expression is rearranged in the following form:

$$Y = Sx - By$$

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[36] George Arceneaux, "A Simplified Method of Making Theoretical Sugar Yield Calculations," International Sugar Journal, XXXVII (1935), 264-265.

where: S is the pol % primary juice.

B is the Brix % primary juice.

x = (29.167) (a) (c) (d)

y = (8.333) (b) (c) (d)

in which: 29.167 is $\frac{\text{lbs. } 96^{\circ} \text{ Sugar}}{\text{(Ton Cane) (\% pol in Primary Juice)}}$

at a pol reduction factor = 1.00, normal juice/cane = 1.00, and BHE = 1.00.

8.333 is $\frac{\text{lbs. } 96^{\circ} \text{ Sugar}}{\text{(Ton Cane) (\% Brix in Primary Juice)}}$

at a Brix reduction factor = 1.00, normal juice/cane = 1.00, and BHE = 1.00

(a) is the pol reduction factor.

(b) is the Brix reduction factor.

(c) is the parts normal juice per part of cane.

(d) is the assumed boiling house efficiency.

Application of the Formula

In varietal milling tests, the control variety and the variety under study are milled to commercial levels of extraction in a hydraulically loaded sample mill by multiple milling (four passes). 18 per cent maceration water is divided between the last three millings.[37]

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[37]George Arceneaux and L. P. Hebert, "Calculation of Sugar Production from Sugar Cane Variety Tests," Sugar, IL (December, 1954), pp. 50-52.

The normal juice extraction and the Brix and pol of the normal juice are calculated. In addition, the Brix and the pol of the juice from the first or primary extraction are determined.

By means of the above data and an assumed boiling house efficiency, the factors x and y are calculated for the control variety and the variety under study. The ratios of x and y give the varietal correction factors for the variety under study. In actual practice, however, a uniform Brix correction factor is assumed.[38] Hence, by applying a standard BHE, the remaining variables then become the pol reduction factor and the normal juice content of the cane. A single Varietal Correction Factor (V.C.F.) reflects the relationship of these variables for the study variety to those of the standard variety.

In subsequent routine evaluations of the variety under study, the Brix and pol of the primary juice (or the juice from a single pass through the sample mill) and the Varietal Correction Factor are applied to the formula in which x and y have been calculated for the standard variety.

Miscellaneous Comments

Arceneaux makes the following generalizations regarding the Sx – By method of cane evaluation:

> "(a) The correction factor for any given variety may be regarded as essentially a constant under Louisiana

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[38]Results from a large number of determinations have shown essentially no difference in Brix reduction factors among varieties.

conditions. It has been found statistically the same whether calculated on plant cane or stubble and was not significantly affected by soil or other environmental variables. Experimental variations are relatively small as indicated by a variability coefficient of 1.7 per cent.

(b) Relatively small lots of cane (80 pounds) are satisfactory for milling studies if adequate precautions are taken to minimize sampling errors. Our cane for such studies ordinarily came from plots or group experiments where plot-arrangement designs, which were employed to overcome effects of soil heterogeneity, ensured highly comparable varietal samples.

(c) An increase in fiber per cent cane caused reductions in the normal juice extraction and the sucrose reduction factor — both tending to reduce the varietal correction factor. The overall relationship is such that given a varietal fiber per cent cane in relation to a control value, it is possible to compute the varietal correction factor with reasonable accuracy. --- V.C.F. values calculated from the following equation did not differ significantly from those computed from results of milling tests.

$$B_{cf} = -0.02265$$

in which B_{cf} is the linear regression of departure in the V.C. F. from 1.00 on departure in fiber per cent cane from that of control.

(d) Fiber content of any given variety will vary from test to test, and it is recognized that calculated sugar yields based on generalized extraction factors could depart from actual values in individual cases. However, in view of the demonstrated constancy of V.C.F. values, this will have no important effect on calculated differences between varieties and that is essentially the purpose of a variety test."[39]

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[39]George Arceneaux, "Standards of Cane Quality in Relation to Agronomic Research and Commercial Evaluation of Mill Cane," Paper delivered before the American Society of Sugar Cane Technologists, February, 1960.

CHAPTER III

METHODS OF SUGAR CANE PAYMENT

Literature references covering sugar cane payment systems are quite limited. This is in marked contrast to information on the subject of cane quality evaluation, which continues to be the subject of intense industry research.

In reviewing the information which is available on cane payment systems, a primary problem appeared to be that of organizing the material into a form which makes for ready comparison of the systems in different cane growing areas. In order to do this, it was necessary to establish certain terms – and to define such terms – to the effect that they would connote the same things in each of the cane payment systems. These terms and their definitions are:

Standard of Cane Quality – This is the unit which is used to define the quality of the cane. The quality of cane may be in terms of recoverable sugar. In Reunion, the standard of cane quality is SE, which is the recoverable sugar of 97^{o} titre % cane.

The Cane Quality Formula – This is the formula to evaluate the cane in terms of the standard of cane quality.

This formula equates some readily measurable quantities as the crusher juice inspections and possibly the fiber % cane to the standard of cane quality.

The Base Price of Sugar – Most cane price formulas base the price paid for cane on the price of raw sugar. Generally, the unit which is used to establish the price of raw sugar is the same as the standard of cane quality. Thus in Puerto Rico, the standard of cane quality is 96° raw sugar. Also, the price of sugar defines the value of the unit of raw sugar as f.a.s., Kingston, or f.o.b., mill. The base price in effect tells one what costs in addition to manufacturing costs are borne by the factory. Thus a base price, f.a.s., implies that the factory costs include those of transporting the raw sugar to the ship side.

The Cane Price Formula – The cane price formula determines the payment to the grower for his cane. Generally this is the payment for sugar only. Payment is usually in cash, although it may be in sugar. If payment is in cash, the cane price formula usually expresses the product of the quality of the cane times the percentage accruing to the grower times the base price of the unit of sugar.

To facilitate comparison, the sections in this chapter covering cane payment systems are divided into the following sub-sections:

General – This is a brief review of the provisions for statutory control of cane prices, the definition of the standard of cane quality, and the cane quality formula. Most of this material is covered in greater detail in the chapter on Methods of Sugar Cane Quality Determination.

The Cane Price Formula (Payment for Sugar) – This sub-section covers the formula used to determine the price to be paid to the grower for his cane. Generally this formula determines the payment to the grower for sugar only.

The Base Price of Sugar – This sub-section defines the value of the unit of raw sugar which is used in the cane price formula.

Payment for Molasses and Byproducts – This sub-section covers the payment to the farmer for molasses and by-products.

Sugar Cane Transportation Costs – This sub-section notes whether the farmer pays the cost of transporting his cane to the factory.

Distribution of Returns - The bases for determining the grower's share in the total returns from his cane are discussed in this sub-section.

Available data on several of the cane payment systems are not complete as to some of the items discussed above.

Since the material on sugar cane payment in Louisiana is rather extensive, this subject is discussed in a subsequent chapter.

QUEENSLAND[1]

General

Statutory control of cane payment is incorporated in the Regulation of Sugar Cane Price Acts, 1915 to 1954 and administered through a Central Sugar Cane Prices Board and local Sugar Cane Prices Boards.

The standard of cane quality is CCS, which is the percentage by weight of a shipment of cane which would be recovered as sucrose if milling and boiling house operations were conducted at a prescribed level of efficiency.

The cane quality formula is:

$$CCS = \frac{3}{2} P \left[1 - \frac{F + 5}{100} \right] - 1/2B \left[1 - \frac{F + 3}{100} \right]$$

[1]The information in this section is based on notes and on correspondence with representatives of the Queensland Industry.

where: P is the pol of the first expressed juice.

B is the Brix of the first expressed juice.

F is the fiber % cane.

The Cane Price Formula (Payment for Sugar)

The Queensland cane price formula, which determines the price to be paid the farmer for sugar, incorporates the concept of CCS as the standard of cane quality, the factory coefficient of work which factors CCS to 94 net titre sugar, and the base price of 94 net titre sugar as set by the Sugar Board.

$$\text{Net Titre (n.t.)} = \text{Pol} - \left[\begin{array}{l}\text{Reducing} \\ \text{Sugars}\end{array} + (5 \times \text{ash})\right]$$

Actual raw sugar production is converted to 94 n.t. sugar as follows:

$$\text{Tons of 94 n.t. Sugar} = \begin{array}{c}\text{Tons Actual} \\ \text{Sugar}\end{array} \times \frac{\text{Actual n.t.}}{94}$$

The coefficient of work, which is based on actual factory performance, is used to compare performance among factories and against accepted standards of performance.

$$\begin{array}{l}\text{Coefficient} \\ \text{of Work}\end{array} = \frac{\text{Tons of 94 n.t. sugar made}}{\text{Tons of CCS in Cane}} \times 100$$

With these concepts in mind, then, the cane price formula is:

$V = .009\ P\,(CCS - 4) + (3s. - 4d.)$

where: V is the price to be paid for a long ton of cane.

P is the base price per ton of 94 n.t. sugar.

3s. - 4d. or 40 pence per ton of cane is an adjustment to the cane payment formula which was made in 1949 as a result of the Sugar Cane Prices Board review of factory and farm costs and assets.

.009 represents a 90 coefficient of work. This factor was originally adopted in setting up the cane price formula.

The CCS as calculated from the cane quality formula may be used directly in determining the cane price if the factory uses the front roller juice – stick fiber method of cane quality determination, or the CCS may be factored to the weekly factory performance if the individual fiber and juice weight evaluation method is used. If used directly, the CCS is determined from the farmer's crop average crusher juice and fiber determinations.

The Base Price of 94 n.t. Sugar

The base price of 94 n.t. sugar is determined annually by the

Central Sugar Cane Prices Board and published in the Central Board Award Price Scale.[2]

The Distribution of Returns

The Central Sugar Cane Prices Board periodically reviews the comparative costs and assets of growers and manufacturers to determine if revisions to the cane price formula are required.

As originally drawn up, the cane price formula was based on average conditions prevailing in the industry at the time, i.e., 12 CCS and a 90 coefficient of work. This gave a split of the returns from sugar of two-thirds to the grower and one-third to the factory. Since the inception of the formula, the state average CCS has increased as has the average coefficient of work. The net effect of these changes, along with the addition of 3s. - 4d. to the grower payment as determined by the formula, has been a slightly higher percentage of the returns accruing to the grower.

REUNION[3]

General

Cane Payment in Reunion is under Government control and is

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[2]To be completely descriptive, the base price should include a place of reference or shipping particulars as f.a.s., Brisbane, or c.i.f., London. Such information is not at hand.

[3]E. Hugot, "Cane Payment on Quality Basis – An Extractable Sugar Formula in Reunion," The International Sugar Journal, LVII (1955), 187-190.

coordinated by the Centre Technique de la Canne et du Sucre. Cane payment provisions apply to cane grown by independent farmers as well as by factory interests.

The standard of cane quality is SE, which is the commercial sugar of 97° titre, % cane, that should be obtained from the cane by a factory operating at certain standards of extraction and retention.

The cane quality formula is:

$$SE = KB_1 \frac{(P_1 - 30)}{100} (1 - 1.4f)$$

where: SE is the extractable sugar of 97° titre % cane.

B_1 is the Brix of the crusher juice.

P_1 is the apparent purity of the crusher juice.

f is the parts fiber per 100 parts of cane.

K is the factory efficiency coefficient by means of which the grower's cane quality is factored to the factory performance – the performance being a function of certain standards of extraction and retention.

The factory determines the factory efficiency coefficient, K, at the completion of the crop. The crusher juice and the fiber inspections for each grower and regional arrangement of growers are crop averages.

The Cane Price Formula (Payment for Sugar)

The cane price formula determines the kilograms of sugar per metric ton of cane, C, accruing to the grower according to his SE.

$$C = \frac{2}{3} SE \times \frac{Kg}{Ton}$$ [4]

Payment for Molasses and Byproducts

The grower receives two-thirds of the profits accruing from the byproducts - rum, alcohol, and molasses. The profits are calculated from the Island average profits for the byproducts per ton on cane and thus are the same for every factory.

SOUTH AFRICA[5]

General

Legislative control of cane payment is through the Sugar Act, 1936, together with the Sugar Industry Agreement, 1943, as amended.

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[4]The cane price formula as so presented infers cane payment for sugar to be in terms of actual sugar. M. Hugot does not note whether the grower receives sugar as payment - in which case it is assumed that he disposes of the sugar through brokers - or whether he receives payment directly for the value of the sugar.

[5]Sugar Act, 1936, together with the Sugar Industry Agreement, 1943, as Amended, Schedule "B", Sections 2, 3, 4.

The control is administered by the Sugar Industry Control Board. Cane payment provisions apply to cane grown by independent farmers as well as by factory interests.

The standard of cane quality is sucrose % cane as determined from the following cane quality formula which relates the grower's crusher juice inspections to the factory Java Ratio.

$$\text{Sucrose \% Cane} = \left[\begin{array}{l}\text{Pol \%}\\ \text{Crusher}\\ \text{Juice}\end{array}\right]_{\text{Grower}} \times \left[\frac{\text{Sucrose \% Cane}}{\text{Pol \% Crusher Juice}}\right]_{\text{Factory}}$$

The Cane Price Formula (Payment for Sugar)

The South African cane price formula is based on 96° sugar. The formula determines the price per ton of cane, C, to be paid to the grower for sugar as the product of the grower's sucrose % cane, the base price of 96° sugar, and a distribution factor. The distribution factor sets the base split between the grower and the factory of the returns from sugar. Additional payments for sugar may accrue to the grower as noted later.

$$C = \text{Sucrose \% Cane} \times \text{Base Price } 96^{\circ}\text{ Sugar} \times 0.533053$$

The grower's sucrose % cane is determined from the weekly average of his crusher inspections and the factory weekly average Java Ratio.

The Base Price of 96° Sugar

The base price of 96° sugar is an average of the local market price and the export price of 96° sugar for the crop.

The local market price is the average price at Hulett's Refinery, Hulsar, of first refined sugar for local consumption – less a refiner's margin.

The export price is the f.a.s. or f.o.r., Durban, price.

Payment for Molasses and Byproducts

> "Growers have the right to participate in any profit that may accrue to millers by reason of molasses becoming valuable as a source of raw material for any product. The extent of such profit and the proportion thereof that shall accrue to the growers shall be determined by the Central Board --"[6]

> In addition, "Growers shall have the right to participate in filter press cake residual -- in accordance with such arrangements as may be made -- between individual mills and their respective Mill Group Boards."[7]

Sugar Cane Transportation Costs

Cane is delivered by the grower at the grower's own expense.[8]

The Distribution of Returns

The distribution factor effectively sets the basic distribution of

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[6] *Ibid.*, Section 54.

[7] *Ibid.*, Section 53.

[8] *Ibid.*, Section 40.

returns from sugar at 53% to the grower and 47% to the factory.

However, various Equalization Funds are also paid to the growers. Essentially these funds are based on each grower's scale of production — becoming increasingly larger for the smaller growers.

In addition, benefits are paid to the factories which produce less than 18,000 tons of sugar annually. The smaller factories receive correspondingly larger payments.

The grower Equalization Funds and the factory benefit payments are financed through levies on the pro-rata production of the factories. Such levies are received and disbursed by the South African Sugar Association, which is an organization of growers and factory owners.

Miscellaneous Comments

In setting the base price of 96° sugar as the average price of local sugar at the Hullet's refinery and of export sugar, f.a.s. or f.o.r., Durban, the factories thus assume the cost of transporting raw sugar from the factory to the refinery, to shipside, or aboard the rail transportation. However, in order that the factories which are located at a great distance from the terminal are not penalized for high transportation costs are shared equitably by all factories as an Industry obligation. Such Industry obligations are met by levies on all factories by the South African Sugar Association. The individual factories are then rebated according to their specific transportation costs.

JAMAICA[9]

General

Although statutory control of the Island industry is provided for under provisions of the Sugar Industry Control Law of 1933 as amended, the control as it affects cane prices is nominal. Such control is incorporated in periodic agreements between the Sugar Manufacturers' Association (SMA) and the All Island Jamaica Cane Farmers' Association (CFA).

Prices paid to the independent cane farmers for cane are currently controlled under the terms of the 1958 Cane Price Formula. The 1958 formula was recommended by an investigator appointed by the SMA and the CFA to propose terms for cane pricing.

The standard of cane quality is the Tons of Cane per Ton of 96° Sugar, TC/TS.

The cane quality formula is:

$$\left[\frac{TC}{TS}\right]_{\text{Farmer}} = \frac{\left[\text{Pol \% Crusher Juice} \times \begin{matrix}\text{W.C. Retention}\\ \text{@ Crusher}\\ \text{Juice Purity}\end{matrix}\right]_{\text{Factory}}}{\left[\text{Pol \% Crusher Juice} \times \begin{matrix}\text{W.C. Retention}\\ \text{@ Crusher}\\ \text{Juice Purity}\end{matrix}\right]_{\text{Farmer}}} \times \left[\frac{TC}{TS}\right]_{\text{Factory}}$$

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[9]The information in this section is based on notes and on correspondence with representatives of the Jamaica Industry.

The Factory TC/TS is determined from the average factory performance for the crop.

The farmer's data are determined from the weighted average crusher juice inspections for the crop.

<u>The Cane Price Formula (Payment for Sugar and Molasses)</u>

$$C = \frac{1}{(TC/TS)_{Farmer}} \times \begin{array}{l}\text{Base Price}\\ 96^{\circ}\ \text{Sugar}\end{array} \times \text{Percentage} - \begin{array}{l}\text{Difference}\\ \text{in Shipping}\\ \text{Expenses}\end{array}$$

where: C is the price paid to the farmer per long ton of cane.

Base Price of 96° Sugar, which includes sugar and molasses, is discussed below.

Percentage is the proportion of the total value of a ton of cane which should accrue to the cane farmer. The percentage is based on factory capacity and varies from 63.38% for four of the smallest factories on the Island to 67.13% for the two largest factories.

Difference in Shipping Expense is an adjustment made to the cane payment to compensate for differences between the individual factory and the Island average raw sugar transportation costs from the factory to a Jamaica terminal and for storage. The factory costs thus include the Island average costs after adjustment for the difference between those costs of the specific factory and the Island average.

The Base Price of 96° Sugar

The base price is the value of one ton of 96° Sugar. This value includes the average price of local consumption and export sugar and the value of the Island average final molasses production per ton of sugar.

The price of local consumption sugar is the average local price less actual refining costs.

The price of export sugar is the average Island f.a.s. price.

The value of the Island average molasses per ton of sugar is based on the f.a.s. export price of molasses.

Payment for Byproducts

The cane price formula includes both sugar and molasses as noted above. Although an appreciable portion of the Island molasses is diverted to rum manufacture – such manufacture being done by the sugar manufacturers themselves – all molasses produced is valued at the price of the molasses which is actually exported. Prior to the 1958 formula, the cane farmers participated in the proceeds from rum, spirits, and molasses.

Sugar Cane Transportation Costs

Cane is delivered to the factory at the cane farmer's expense.

The Distribution of Returns

A 1945 industry survey commission completed a comprehensive study of the industry and its costs, assets, and returns. Based on these studies, the commission proposed a cane payment formula. The formula, in arriving at the price to be paid to the cane farmer, deducted from the sugar revenues an average manufacturing cost and manufacturing profit to arrive at the return to the cane farmer per TC/TS for sugar. In addition, the formula included proceeds per ton of cane for byproducts, i.e., rum, spirits, and molasses. This formula was never incorporated in subsequent cane price agreements.[10]

In 1960 a commission investigated the 1959 sugar industry strike. The industry survey included sugar cane production, raw sugar manufacturing, and rum, spirits, and molasses costs, returns, and assets. To date, the result of the economic studies have not been incorporated in subsequent cane price agreements.[11]

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[10] Report of the Sugar Industry Commission - Jamaica - 1944-45. Kingston: The Government Printer, 1945.

[11] Report of the Commission of Enquiry on the Sugar Industry of Jamaica. Kingston: The Government Printer, 1960.

MAURITIUS[12]

General

Cane payment is governed by the Sales of Cane (Central) Ordinance No. 47 of 1941. Statutory Control is vested in the Central Arbitration and Control Board.

The standard of cane quality is commercial sugar of 99 purity % cane.

The cane quality formula relates the grower's "true" sucrose % cane to a standard reduced extraction based on his fiber % cane and a standard retention based on his mixed juice purity.

$$\begin{array}{c} \text{Yield, 99} \\ \text{Purity Comm.} \\ \text{Sugar \% Cane} \end{array} = \begin{array}{c} \text{"True"} \\ \text{Sucrose} \\ \text{\% Cane} \end{array} \times \begin{array}{c} \text{Reduced} \\ \text{Extraction} \end{array} \times \begin{array}{c} \text{Standard} \\ \text{Retention} \end{array} \times \frac{1}{98.5}$$

As applied in actual practice, the grower's inspections (Brix and apparent purity of the first expressed juice and fiber per cent cane) are factored to the mill inspections during the period in which he delivered his cane (test period) and then factored again to reflect the difference between the factory inspections at the time of the delivery and the average factory inspections for the crop. Fixed standards of factory extraction and boiling house performance are applied in determining the yield of sugar.

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[12] The information in this section is based on personal notes covering the Mauritius Industry.

The Cane Price Formula (Payment for Sugar)

The cane price formula, which represents the planter's payment for sugar, determines the amount of sugar which the planter receives in payment for his cane.

$$C = \begin{matrix}\text{99 Purity}\\ \text{Sugar \%}\\ \text{Cane}\end{matrix} \times \frac{\text{Kg.}}{\text{Ton}} \times \begin{matrix}\text{Distribution}\\ \text{Factor}\end{matrix} - \begin{matrix}\text{Equivalent Sugar}\\ \text{for Cane Loading}\\ \text{\& Transportation}\\ \text{Costs.}\end{matrix}$$

where: C is the kilograms of sugar per ton of cane accruing to the grower.

Distribution Factor is the fraction of sugar accruing to the grower as determined by the Central Board.

Equivalent Sugar for Cane Loading & Transportation Costs represents the costs incurred in hoisting and transporting the cane using the factory facilities.

The Base Price of 99 Purity Commercial Sugar

The cane price formula determines the grower's returns for sugar in terms of actual sugar. When the grower elects to be paid in cash rather than sugar, he is paid on the basis of the net price per ton of 99 purity commercial sugar at the docks, In this case, handling, storage, shipping, and insurance charges are deducted from the gross receipts for sugar to arrive at the net price per ton of sugar. The factory costs, of course, include those of transporting the raw sugar from the factory to the docks.

Payment for Molasses and Byproducts

In addition to his share of sugar, the planter is entitled to two-thids of the average amount of scums and molasses produced by the factory per ton of cane.

Sugar Cane Transportation Costs

As noted in the section on the payment for sugar, the planter bears the cost of loading and transporting his cane. Generally, the factory performs these services and the Island average costs are annually determined on a ton-mile basis. The Island average costs are then applied to the planter's deliveries.

The Distribution of Returns

The Central Board, in setting the basis for cane payment, recognizes the principle that under normal conditions the planter should receive an average of two-thirds of the sugar which his cane might be expected to yield. Periodic surveys are made of the costs of production of cane and raw sugar manufacture. In setting the amount of sugar accruing to the planter based on these surveys, consideration is given to the fact that certain factories and planters need more than the island average distribution in order to stay in business.

PUERTO RICO[13]

Dual statutory control of the Puerto Rican Sugar cane industry is provided in the Puerto Rican Sugar Act which is administered by the Island Department of Agriculture and Industry through the Sugar Board - and the United States Sugar Act which is administered by the Sugar Division of the United States Department of Agriculture.

The regulations of the Insular Sugar Act are general - covering the relations between the factories and growers, rules and regulations for sampling and analyzing cane, and the payment for cane to the farmers. Through hearings, the Sugar Board prescribes orders, directives, etc., which are necessary for the exercise of its duties.

The regulations of the Federal Sugar Act cover provisions which must be met by industry members to qualify for the Sugar Act benefit payments. These provisions, while restricted to production of cane, essentially cover the entire industry since factory interests as well as the independent farmers cultivate cane. As the federal control affects the price paid for sugar cane, it is implemented through annual cane price hearings in Puerto Rico which are conducted by representatives of the Sugar Division. The basis for the cane price as so determined

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[13]The information in this section is taken from the Sugar Act of Puerto Rico of May, 1951, and the Puerto Rican 1959-60 Crop Fair Price Determination S.D. 877.13, United States Department of Agriculture.

is applicable to cane grown by factory interests as well as by independent farmers – both referred to as producers.

As covered in the following summary, the provisions for cane payment in both the Island and Federal regulations are essentially similar.

Sugar cane is valued on a net cane basis, where net cane is cane containing not in excess of 5% trash.[14] The net weight of sugar cane is determined by detrashing a sample of gross cane weighing about 100 pounds. The weight of the trash removed is expressed as a percentage of the gross weight of the sample. If such a percentage exceeds five per cent, the difference between 100% and the excess percentage is applied to the gross weight of the sugar cane from which the sample was removed to determine the net weight of such sugar cane.

The standard of cane quality is pounds of 96° raw sugar per 100 pounds of net cane.

The cane quality formula is:

$$R = TI\,(S - 0.3B)\,F$$

where: R is the yield of 96° sugar per 100 pounds of net cane.

T is the trash correction factor which is equal

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[14]"Trash" means green or dried leaves, sugar cane tops, stones, and all other extraneous material.

to 1.00 for cane with 5% or less trash, 0.99 for 6% trash, 0.98 for 7% trash, etc.

I is a correction factor which is applied only to inferior varieties of cane and which is a function of the purity of the crusher juice samples.

S is the pol of the crusher juice sample.

B is the Brix of the crusher juice sample.

F is the yield factor which is the quotient of the actual weight of 96° raw sugar produced by the factory during the settlement period divided by the sum of the "tentative recoveries of raw sugar" for all producers.

$$F = \frac{\text{Weight of } 96^{\circ} \text{ Raw Sugar Actually Produced by the Factory}}{\text{Sum } W \times T\ I\ (S - 0.3B)}$$

where: Sum W x T I (S-0.3B) is the sum of the product of the weight of each producer's cane delivery, W, times his "tentative recovery of raw sugar," T I (S-0.3B).

The run periods for which the factory determines the factory F may not exceed one month. The crusher juice inspections for each producer are averaged for the same period.

The Cane Price Formula (Payment for Sugar)

$$C = R \times \% \times \text{"Price of Raw Sugar"}$$

where: C is the payment to the producer per 100 pounds of net sugar cane.

R is the yield of 96° raw sugar per 100 pounds of net sugar cane.

% is the percentage of the yield of 96° sugar which accrues to the producer. This percentage varies from 63.0% for a yield of 9.0 pounds of 96° raw sugar per 100 pounds of net sugar cane to 67.5% for 13.5 pounds and over of 96° raw sugar per 100 pounds of net sugar cane. This is in effect an incentive system in which the producer is paid an increasingly large percentage of the yield for higher cane quality.

Actually, cane payment for sugar may be in cash as determined above, or in sugar in which case the cane payment is:

$$C = R \times \%$$

where: C is the payment to the producer in pounds of raw sugar per 100 pounds of net sugar cane.

Base Price of 96° Raw Sugar

The base price is the value of 96° raw sugar, f.o.b. factory. To arrive at this figure, selling and delivery expenses are deducted from the simple average price of raw sugar for the crop year as quoted on the New York Coffee and Sugar Exchange.

The selling and delivery expenses include freight from the mill directly to the dock, receiving, handling, lighterage (if bagged), loading, ocean freight, and unloading costs as well as an allowance for insurance, brokerage, and weighing and testing costs.

Payment for Molasses

The producer is paid for molasses per net ton of sugar cane delivered to the factory. This payment is equal to the product of 66% of the net factory proceeds per gallon of molasses times the factory average production of blackstrap molasses per net ton of cane.

The net factory proceeds from molasses are determined by deducting from the average gross sales price admissable selling and delivery expenses. These selling and delivery expenses include pumping costs from the factory storage tank, freight costs, and weighing, testing, and brokerage costs.

Distribution of Returns

The considerations in annually setting the basis for cane payment are well stated in the fair price determination:

> "Analysis of the comparative costs, returns, and profits of producing and processing sugarcane obtained through field survey for prior years and recast in terms of the prospective price and production conditions for the 1959-60 crop, indicates that the sharing relationship between producers and processors provided in this determination is equitable."[15]

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[15] *Ibid.*, p. 3.

CHAPTER IV

SUGAR CANE QUALITY DETERMINATION AND CANE PAYMENT IN LOUISIANA

GENERAL

Social and Economic Conditions[1]

Through the ten year period of 1952 through 1961, sugar cane production for sugar in Louisiana has averaged 6,366,000 gross tons annually, with 1961 witnessing a record production of 7,659,253 tons. The comparable raw sugar production in 96° raw sugar value was 468,900 tons as the ten year average with a record production of 642,000 tons in 1961.

Annual factory throughput averaged 117,700 gross tons of cane in the period 1952 through 1961, with a peak throughput of 166,506 tons in 1961. Comparable raw sugar production was 9,420 tons as the ten year average, and a record production of 13,960 tons in 1961.

Amalgamation of the processing segment of the industry has

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[1]The statistical material in this section covering the period 1952 through 1961 is abstracted from the Special Statistical Issue of The Sugar Bulletin, XXXIX (1961). The 1961 crop data are based on preliminary reports released by the Agricultural Stabilization and Conservation Service – Louisiana State Office, United States Department of Agriculture.

been fairly extensive. Whereas there were 54 factories in operation in 1952, the 1961 crop was handled by 46 factories.

The state factories vary widely in capacity, ranging from about 70 to 185 gross tons of cane per hour. Nine of the factories are farmer-owned cooperative enterprises. The cooperatives grind about twenty-five per cent of the state cane production.

The average factory yield (1952-1961) was 170.2 pounds of 96° raw sugar per net ton of cane. 1958 and 1961 were record years with yields of 182.0 and 182.3 pounds respectively.

The number of growers supplying each Louisiana factory varies considerably. At one extreme, one Louisiana factory of about state average capacity receives cane from about 440 growers, while at the other extreme, a factory of comparable capacity receives cane from about 32 growers.

There has been an amalgamation of farms in the industry, with the number of sugar cane farms decreasing from 4,463 in 1952 to 2,547 in 1960. The average size per farm has increased correspondingly from 66.0 acres in sugar cane in 1952 to 110.6 in 1961.

The farms vary considerably in size. While about 80 per cent of the farms are under 100 acres in size (about 42 per cent are under 25 acres), 78 per cent of the cane is grown on farms of 100 acres and over in size.

The ten year average farm yield has been 22.4 net tons of cane per acre. 1955 and 1961 were record years with yields of 24.4 and 25.5 net tons of cane per acre.

About 50 per cent of the Louisiana cane production is factory administered or grown by cooperative factory owners.

The Legislative System

U. S. sugar cane and sugar beets initially were placed on a quota basis under the provisions of the Jones-Costigan Act of May 1934. This act was an amendment to the sweeping Agricultural Adjustment Administration (A.A.A.), which was designed to relieve the depression born distress of the country's agriculture.

Among other things, the Jones-Costigan Act provided for benefit payments to sugar cane producers from revenues derived from a processing tax of one-half cent per pound of refined sugar. It was the intent of the Act that, through the benefit payments, the cane producers would be guaranteed a parity price of equivalent buying power of sugar cane - referred to the base period of 1909-1914. The benefits were to accrue to those producers who complied with the quota and other provisions of the Act.

Although the benefit payment provisions of the Jones-Costigan Act were nullified by a Supreme Court ruling, the Sugar Act of 1937 reestablished the primary essentials of the former Act.

The 1937 Act was subsequently amended in 1941, 1944 and again in 1946, and expired on January 1, 1948. Presently, the U. S.

sugar industry is administered under the Sugar Act of 1948 as amended.

Basically, the Sugar Acts have been designed to maintain a healthy and competitive domestic sugar industry of limited size; to assure adequate sugar supplies to consumers at reasonable prices; and to promote this country's general export trade.[2] Specifically, the Acts include provisions for:

1. Maintenance of the Price of Sugar: The intent of the Sugar Acts is to maintain the price of sugar at such a level as to assure the consumer an equitable price and to provide a fair return to the domestic sugar producing industry. This control is exercised by the Secretary of Agriculture through the determination - after public hearings in the fall of each year - of the predicted annual sugar consumption (raw value) for the continental United States. This determination effectively establishes the quantity of sugar in short tons raw value that may be marketed in the United States during the year under consideration. (By provisions of the Acts, the portion

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[2] The United States Sugar Program, Agricultural Information Program Bulletin No. 111, United States Department of Agriculture, Washington, D.C., July, 1953, p. 50.

of the total consumption accruing to the United States industry is fixed.)

In setting the annual sugar requirements, and in subsequent revisions of the initial determination, the Secretary of Agriculture is able to control the price of raw sugar. A predicted high sugar consumption may result in a drop in the price of raw sugar if the actual refiners' demands do not meet the prediction. By the same token, a predicted low consumption may result in a subsequent high price of sugar because demand proves to be greater than anticipated.

2. Establishing Quotas to Domestic and Foreign Producing Areas: After the Secretary has determined the annual sugar requirements, each domestic and foreign producing area supplying the country with sugar is assigned a quota representing its share of the market.

3. Establishing Marketing Allottments to Marketers: One important function of the sugar program is to promote orderly marketing. The establishment of quotas can usually accomplish this. However,

sometimes quotas are not enough – especially when supplies in the producing areas materially exceed the quotas. If the Secretary believes that the pressure of supplies in a certain domestic area is likely to cause disorderly marketing, he must allocate the quota fairly among the marketers, factories or importers in the area.

4. Assigning Proportionate Shares: For domestic areas, the Sugar Act requires the Secretary of Agriculture to divide the market among individual farms. Each farm's allotment, known as its "proportionate share", may be expressed in acres, tons of sugar cane or beets, or in tons of sugar, raw value, which can normally be produced from cane or beets.

   In actual practice, proportionate shares are not made restrictive unless production in an area has exceeded or promises to exceed the quota, and the marketing allotments have failed to bring about a balance between production and allowable area marketings. Marketing allotments are applied when excessive production and disorderly marketing first become a problem. Sometimes the allotments are sufficient to cause growers to bring production more nearly in line with quotas. However, if the trend to increase crop output is strong, making proportionate shares restrictive is usually needed to bring about the proper balance.

5. Assuring a Fair Distribution of the Benefits of the Sugar Program to the Grower, the Field Worker, and the Factory Owner: This objective is accomplished primarily through the provisions for benefit – or conditional – payments to the growers. Basically, the objectives of the conditional payments are (a) to induce the growers to adjust their production to the quota and carry-over needs; (b) to help provide adequate income to the growers; (c) to prevent employment of child labor in field work; and (d) to assure growers, field workers, and factory owners a fair sharing of the returns to the industry.

The last objective is accomplished through annual field wage determinations and cane and beet fair price provisions. The fair price provisions are enforceable since growers who are also processors (manufacturers) are required to pay prices for cane and beets in accordance with the fair price provisions in order to receive conditional payments. (In Louisiana, all processors are also growers – either through cane growing interests owned by the factory, or owned by the factory owners themselves.)

Fair prices are determined annually by the Secretary in each domestic cane or beet area after public hearings and after investigation of the economic position of the growers and processors. The hearings are conducted by representatives of the Sugar Division of the Department of Agriculture. The testimony which has been presented by the grower and the processor representatives – along with factory and farm cost and return data which have been collected by Sugar Division area survey teams – is subsequently reviewed to arrive at the basis for determining the beet or cane fair price provisions for the forthcoming crop. The annual fair price determinations are issued in printed form prior to the start of the crop.

In Louisiana, an industry grower-processor committee supervises the contractual relations between the growers and processors. Generally, the industry position is presented before the annual hearings by a representative of the committee. One year a grower member submits the committee recommendations and the next year a processor member makes the presentation. In several instances, the grower-processor committee has not been able to reach an agreement on recommendations to be submitted at the hearing. In such cases, separate briefs have been presented by the processor and grower segments of the industry. It has been the custom of the Sugar Division representatives to permit individual members of the industry - growers or processors -- to enter in testimony data or recommendations which may not have been included in the briefs of the industry representatives.

The conditional payments for cane are based on the predicted recoverable sugar content of the cane. In addition, the rates of the payments vary with the volume of sugar, raw value, produced from the cane grown on a farm. The rates are graduated downward from the small to the large producer. The basic rate of \$.80 a hundred pounds of sugar, raw value, is paid on the first 350 short tons produced on a farm. This rate is reduced progressively to a minimum of \$.30 a hundred pounds on all sugar produced in excess of 30,000 short tons on a farm.

The sugar program also provides limited benfits for growers in the form of special conditional payments for crop deficiency or abandonment caused by drought, flood, storm, freeze, disease, or insects. Total benefit payments to the Louisiana cane farmer currently average about $1.20/net ton of cane.

The conditional payments are financed out of the general funds of the U.S. Treasury. However, a tax on sugar provides funds for the Treasury which more than offset the total of all conditional payments, plus the costs incurred in administering the Sugar Act. This tax is in the amount of one-half cent a pound, raw value, on all sugar processed and imported for direct consumption. It is imposed on domestic processors – refiners and beet processors – and on importers of direct consumption sugar.

Harvesting

In Louisiana, the harvesting operation is essentially 100 per cent mechanical. The typical mechanical harvester cuts the cane top and bottom and discharges the cane to the ground. Cane is mechanically loaded into tractor-drawn carts which deliver the cane to field hoists – or direct to the factory if the field is in close proximity to the factory. While the larger farms may own mechanical harvesters, the smaller units harvest by contract.

The general practice of mechanical harvesting has resulted in a high incidence of trash accompanying the cane, i.e., immature joints either loose or still adhering to the stalks, leaves, soil, and in some cases stools. When weather permits, it is general practice to burn the cane after harvesting, to remove the foliage. In rainy weather this is not possible and the trash accompanying the cane may vary from 10 to 20 per cent.

Most Louisiana factories wash the cane at the factory. Provisions for laundering the cane include high velocity water nozzles and modifications of the feeder tables to permit maximum contact of cane with the wash water as the cane enters the carrier. Washing may be intermittent or continuous. Many factories wash cane only during periods of rainy weather when a high incidence of field soil accompanies the cane. At such times the practice is <u>necessary</u> because of the refractory effect on the milling operation (slippage and wear), lowered clarification capacity, and high sucrose losses in the filter muds.

Cane Transportation

The quantity of cane delivered to the Louisiana factory may vary from as little as three tons per day per shipper to several hundred tons.

For transportation from the field to the factory the cane is generally secured with chains into bundles which weigh from two and one-half to three tons.

Primarily the cane is transported by truck trailers which haul from 15 to 30 tons of cane per load from field hoist to the factory. The transportation may be factory owned, farmer owned, or contracted. In addition, a substantial portion of the cane from areas in close proximity to the factories is delivered in tractor drawn carts which handle from two and one-half to five tons of cane. Some cane is delivered in standard gauge railway cars (common carriers), plantation railroad cars, and by barge.

CANE QUALITY DETERMINATION

Sampling

The practice of washing the cane entering the carrier, the small size of the individual cane deliveries relative to the capacity of many of the factories, and the fact that most cane is delivered during the daylight hours – these factors have resulted in the almost universal use of the three-roll sample mill for direct cane quality determination, although a few factories still base their cane quality determination on crusher juice samples.

Samples are removed from the cane conveyance for trash determination and for sucrose and purity determination by the three-roll sample mill.

The frequency of sampling for trash and for sucrose and purity (as well as the prescribed methods of testing) is specified in the procedure published annually by the Sugar Division titled Sampling, Testing, and Reporting Procedure to be Followed by Louisiana Sugar Mills Under the Sugar Act Determination. Practically, because of the wide variation in factory capacity and in the number of growers delivering to each factory, the sampling frequency of the individual factories varies. This is illustrated in Table I which shows for 14 factories the number of shippers supplying the factory, the average number of shippers delivering daily, the average frequency of sampling for trash and for sucrose and purity (in terms of the average tons of cane per test), and the cost of the trash and the sucrose and purity tests.[3] The specific sampling practices in selected factories are discussed in detail in reports prepared by the L.S.U. Department of Chemical Engineering under a contractual program with the United States Department of Agriculture covering sugar cane sampling and evaluation in Louisiana.[4,5]

Samples for trash and for sucrose and purity may be by hand or by mechanical grab. In the latter case, the samples are removed

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[3] Progress Report No. 2 – A Study on Sampling and Methods of Determining Sucrose, Purity, and Fiber Content of Sugar Cane, USDA Contract No. 12-25-010-558, p. 15.

[4] Ibid., pp. 2-18.

[5] Final Report – A Study on Sampling and Methods of Determining Sucrose, Purity, and Fiber Content of Sugar Cane, USDA Contract No. 12-25-010-558, Exhibit I.

TABLE I

FREQUENCY AND COST OF SAMPLING

1957-58 CROP

Name of Factory	No. of Cane Shippers		Testing Cane for Trash			Testing Cane for Sucrose & Purity		
	Total	Av./Da.	Av. Tons Cane/Test	Av. Man Hrs./Test	Av. Cost per Test	Av. Tons Cane/Test	Av. Man Hrs./Test	Av. Cost per Test
A	41	26	61.15	1.12	$1.26	104.87	3.22	$1.10
B	34	31	52.95	0.83	0.86	54.72	0.76	0.87
C	36	20	43.45	0.16	0.73	73.87	0.67	1.79
D	301	120	26.48	0.44	0.74	15.97	0.24	0.46
E	568	225	33.38	0.61	0.61	11.02	0.54	0.55
F	32	21	48.85	1.13	1.30	91.61	0.93	1.04
G	220	45	29.01	1.04	1.09	29.01	0.31	0.36
H	41	20	39.30	1.01	1.08	30.92	0.41	0.42
J	44	6	61.03	0.34	0.39	142.81	1.89	2.17
K	110	80	50.74	0.19	1.48	52.21	0.20	0.64
L	185	98	43.84	0.75	1.29	14.34	1.63	2.82
M	122	34	34.32	0.61	0.67	34.32	0.59	0.65
N	204	138	23.10	0.98	1.09	5.55	0.44	0.56
O	45	24	44.11	1.20	1.410	88.81	1.04	1.47

from the opened bundle of cane by a hydraulically operated grab which is capable of handling a sample of 40 to 120 pounds of cane.

Trash - If the bundle is placed on the feeder table, a 50-100 pound sample is removed by mechanical grab or by hand. If the bundle is placed on the ground, a 50-100 pound sample is removed by hand. The gross cane is weighed, detrashed, and the net cane is weighed. From these data, the per cent trash is determined.

Sucrose and Purity - Samples are removed either by mechanical grab or by hand. If mechanical grab, a sample is removed from the opened bundle on the feeder table. The sample may be ground directly or it may be composited with other samples from the same grower and ground at the end of the day. If the sample is by hand, a hand "grab" of 20 to 40 pounds may be taken from the opened bundle and the sample ground directly. Or 2 to 10 stalk samples may be removed per bundle. These stalks are composited with other samples from the same grower and ground at the end of the day.

Testing and Evaluation

The cane samples - either direct or composited - are ground in the three-roll sample mill and the juice samples analyzed for apparent sucrose (pol) by the Horne's dry lead method and for Brix by hydrometer. The sample mills may be either fixed setting or hydraulically loaded. Several factories use two three-roll sample mills in tandem to obtain greater extraction severity.

Normal Juice: Cane quality in Louisiana is based on the concept of normal juice. Normal juice is defined as the juice extracted from sugar cane by a mill tandem when no maceration water is used, i.e., undiluted juice. Since maceration water is used to increase the milling efficiency, it is necessary to calculate the factory normal juice inspections from the crusher and mixed juice inspections and a milling factor. The grower's normal juice quality is determined by applying similar factors to his sample mill juice inspections.

Standard Cane: By means of the normal juice inspections it is possible to determine the standard cane. Standard cane is in effect the standard of cane quality in Louisiana. Standard cane is defined as net sugar cane (gross cane minus trash) containing 12 per cent pol in normal juice with a purity at least 76.00, but not more than 76.49 per cent. Net sugar cane is converted to standard sugar cane through the application of Quality (normal juice pol) Factors and Purity (normal juice purity) Factors. This computation is the Louisiana cane quality formula as shown below:

$$\text{Standard Sugar Cane, Tons} = \text{Net Sugar Cane, Tons} \times \begin{pmatrix}\text{Quality} \\ \text{Normal Juice} \\ \text{Pol} \\ \text{Factor}\end{pmatrix} \times \begin{pmatrix}\text{Purity} \\ \text{Normal Juice} \\ \text{Purity} \\ \text{Factor}\end{pmatrix}$$

where: Net Sugar Cane for each grower is determined from his trash inspections.

The Quality Factor for each grower is determined from his normal juice pol through the following relationship:

Pol % Normal Juice	Quality Factor
9.5	0.60
10.0	0.70
10.5	0.80
11.0	0.90
11.5	0.95
12.0	1.00
12.5	1.05
13.0	1.10
13.5	1.15
14.0	1.20
14.5	1.25

The quality factors were originally determined from a review of Louisiana factory run reports in which the normal juice pol was related to the actual factory raw sugar yields.

The Purity Factor for each grower is related to his normal juice purity through tables which accompany the annual cane price determinations. The purity factors were incorporated in the 1949 determination to encourage the delivery of fresh cane. These factors are based on the calculated retention by the Winter-Carp formula at various normal juice pol levels. Essentially these factors represent premiums and penalities above and below the state average purities corresponding to the different normal juice sucrose levels.

Dry Milling Factor: The dry milling factor provides the means by which the factory normal juice Brix is calculated from the crusher juice Brix. The dry milling factor relates the normal juice Brix to the crusher juice Brix as follows:

$$\text{Dry Milling Factor} = \frac{\text{Normal Juice Brix}}{\text{Crusher Juice Brix}}$$

The dry milling factor may be either 0.97 as specified in the Louisiana Sampling, Testing, and Reporting Procedure, or it may be determined by actual dry milling tests.

When maceration water is applied to the mill tandem, the normal juice Brix is then calculated from the crusher juice Brix in the following manner:

$$\text{Factory Normal Juice Brix} = \text{Factory Crusher Juice Brix} \times \text{Dry Milling Factor}$$

The factory normal juice purity is assumed to be that of the factory dilute juice or mixed juice. The normal juice pol is then determined from the product of the normal juice Brix and the normal juice purity as follows:

$$\text{Factory Normal Juice pol} = \text{Factory Normal Juice Brix} \times \text{Factory Normal Juice Purity}$$

Dilution Compensation Factor (DCF): Where cane is washed, it is not possible to determine the factory normal juice Brix by applying the dry milling factor to the diluted crusher juice Brix. In this case it is necessary to determine a dilution compensation factor which relates the factory "undiluted" crusher juice Brix to the sample mill Brix.:

$$\text{Dilution Compensation Factor} = \frac{\text{Crusher Juice Brix}}{\text{Sample Mill Brix}}$$

Thus when wash water is applied to the cane in the carrier, the daily "undiluted" crusher juice Brix is calculated from the daily average sample mill Brix and the dilution compensation factor in the following manner:

$$\text{Daily Undiluted Crusher Juice Brix} = \text{Daily Average Sample Mill Juice Brix} \times \text{Dilution Compensation Factor}$$

The dilution compensation factor is determined a minimum of three times per crop in the following manner: For a period of at least one hour, the wash water is discontinued and the cane enters the knives and crusher "dry". During this period, samples of cane are removed from the carrier and samples of crusher juice are composited. At the end of the hour, the cane samples are processed through the sample mill. The crusher and sample mill juice samples are analyzed for Brix, and the dilution compensation factor is determined.

Sample Mill Brix and Pol Factors:[6] Having determined the daily average factory normal juice Brix and pol, it is then possible to calculate the normal juice Brix, pol, and purity for each grower from the grower's sample mill inspections and sample mill Brix and pol factors.

The sample mill Brix and pol factors relate the factory normal juice Brix and pol to the sample mill Brix and pol for the corresponding period in the following manner:

$$\text{Sample Mill Brix Factor} = \frac{\text{Factory Normal Juice Brix}}{\text{Sample Mill Juice Brix}}$$

$$\text{Sample Mill Pol Factor} = \frac{\text{Factory Normal Juice Pol}}{\text{Sample Mill Juice Pol}}$$

The sample mill juice Brix and pol are determined in the following manner: During the same 24 hour period in which the factory

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[6]A comprehensive study of Louisiana sample mill factors and their variation from factory to factory is presented by W. M. Grayson in "A Study of the Factors Affecting Growers' Juice Samples," Proceedings American Society of Sugar Cane Technologists 1946-1950, (February, 1953), pp. 176-189.

normal juice Brix and pol are calculated, the net weight of each cane delivery and the corresponding sample mill Brix and pol are tabulated. The daily average sample mill Brix and pol are then determined from the simple average or the weighted average sample mill data.

The normal juice pol and purity for each grower are then calculated by applying six-day moving average sample mill Brix and pol factors to the grower's sample mill inspections as follows:

$$\text{Grower's Normal Juice Brix} = \text{Grower's Sample Mill Juice Brix} \times \text{Six-Day Moving Average Sample Mill Brix Factor}$$

$$\text{Grower's Normal Juice Pol} = \text{Grower's Sample Mill Juice Pol} \times \text{Six-Day Moving Average Sample Mill Pol Factor}$$

$$\text{Grower's Normal Juice Purity} = \frac{\text{Grower's Normal Juice Pol}}{\text{Grower's Normal Juice Brix}}$$

The moving average factors are determined daily by averaging the factors for each day and the five days preceding.

<u>Cane Sampling by Crusher Juice Inspections</u>: When the grower's cane is sampled by crusher juice inspection instead of by the sample mill, his normal juice quality is determined by multiplying his crusher juice Brix and pol by the corresponding Brix and pol factors as follows:

$$\begin{array}{lll} \text{Grower's} & \text{Grower's} & \text{Brix} \\ \text{Normal Juice} = & \text{Crusher Juice} \times & \text{Factor} \\ \text{Brix} & \text{Brix} & \end{array}$$

$$\begin{array}{lll} \text{Grower's} & \text{Grower's} & \text{Pol} \\ \text{Normal Juice} = & \text{Crusher Juice} \times & \text{Factor} \\ \text{Pol} & \text{Pol} & \end{array}$$

The Brix and pol factors are the ratio of the daily factory normal juice Brix to the crusher juice Brix and the ratio of the daily factory normal juice pol to the crusher juice pol.

SUGAR CANE PAYMENT[7]

The Cane Price Formula (Payment for Sugar)

The cane price formula applies equally to cane supplied by independent growers and to factory owned (administration) cane.

$$C = \begin{array}{l} \text{Grower's} \\ \text{Standard} \\ \text{Sugar Cane} \end{array} \times \begin{array}{l} \text{Basic Price} \\ \text{For Standard} \\ \text{Sugar Cane} \end{array} + \begin{array}{l} \text{Cane} \\ \text{Transportation} \\ \text{Allowance} \end{array}$$

where: C is the price to be paid to the grower for sugar, $.

Grower's Standard Sugar Cane is the cane quality as determined from the cane

[7]The information in this section represents the recent cane price provisions as they are shown in the Louisiana 1961 Crop Sugar Cane Price Determination, Sugar Determination 874.14, United States Department of Agriculture.

quality formula, tons.

The Basic Price for Standard Sugar Cane is based on the sugar cane pricing factor and the adjusted average price for raw sugar.

Basic Price For Standard Sugar Cane, \$/Standard Ton of Cane	=	Sugar Cane Pricing Factor, \$/Standard Ton of Cane per One ¢/lb. of 96° Raw Sugar	x	Adjusted Average 96° Raw Sugar Price, ¢/lb.

The Sugar Cane Pricing Factor in effect sets the split of returns between the grower and the processor.

The Adjusted Average 96° Raw Sugar Price is the average quoted 96° raw sugar price as corrected with a raw sugar freight differential. Through the raw sugar freight differential, the growers participate in raw sugar transportation costs from the factory to the refinery.

Adjusted Average 96° Raw Sugar Price, ¢/lb.	=	Average 96° Raw Sugar Price, ¢/lb.	−	Raw Sugar Freight Differential, ¢/lb.

Cane Transportation Allowance covers the costs of hoisting and transporting the cane which are incurred by the grower in delivering his cane from the field hoist to the factory or from the farm directly to the factory.

Price of 96° Raw Sugar

The base price of sugar, as used in determining the basic price for standard sugar cane, is the average price of 96° raw sugar as quoted by the Louisiana Sugar Exchange, Inc., New Orleans, Louisiana. The price in the cane payment formula may be either the weekly average or the seasons' average price.

Payment for Molasses and By-products

The grower is paid for molasses per net ton of sugar cane which he delivers to the factory. Currently the payment is equal to the product of 6.6 gallons times one-half the average price per gallon of final molasses in excess of six cents. The average price of final molasses is the price quoted by the Louisiana Sugar Exchange. The price may be either the weekly or the season's average price.

Sugar Cane Transportation Costs

Transportation allowances to the growers are based on net cane. These allowance cover costs incurred by the grower in delivering cane from field hoists to the factory or directly from the farm to the factory.

Many factories provide the facilities directly or by contract — and thereby assume the costs — for hoisting and transporting the sugar cane from the field hoists to the factory. If the growers provide these services — either directly or by contract — they are reimbursed. In such cases the rates are those mutually agreed upon between the factory and growers. However, such rates are usually conditioned by contract hauling and hoisting services in the area.

In the case of farms located in close proximity to the factory — in which event cane is usually delivered by tractor-drawn carts — the factories also pay transportation allowances. The maximum allowances which may be paid are specified in the cane price determination.

Raw Sugar Transportation Costs

The average price of 96° raw sugar as quoted by the Louisiana Sugar Exchange is essentially the price of raw sugar delivered to New Orleans (the area of heaviest raw sugar refinery concentration). The growers participate in the raw sugar transportation costs from factories in the "high cost" freight areas to New Orleans. There are effectively three freight rate areas in the sugar belt. As set up in the 1949 determination, the area closest to New Orleans was recognized as the base freight area. The differences in freight costs between the other two areas and the base area were shared — two-thirds of the difference was borne by the growers delivering to the factories in these areas (the raw sugar freight differential) and one-third by the factories.

The freight rates in the three areas – as set by the Interstate Commerce Commission – have varied over the years; however, the freight differentials (as periodically revised) have continued the two-thirds and one-third sharing relationship. With the drop in freight rates in recent years, the growers in the base area are now credited with their share of the decrease from the 1949 freight rate.

Payment for Sub-Standard Cane

Two categories of sub-standard sugar cane are recognized, i.e., salvage cane and frozen cane. Salvage sugar cane is defined as sugar cane containing either less than 9.5 per cent sucrose in normal juice or less than 68 per cent purity in the normal juice.

Frozen sugar cane may be either freeze-damaged cane such that the boiling house operations are adversely affected – or cane damaged in a general freeze such that abnormally low sugar recovery results.

Generally, payment for salvage sugar cane is by the Scaled Down Method in which quality and purity factors for standard cane are scaled down to reflect the lower sugar cane quality. Some factories use the Winter-Carp Method in which the returns for sugar and molasses are predicted from the boiling house retention formula using assumed values of boiling house efficiency and normal juice extraction. The grower's cane payment is calculated after deducting a processing charge from the calculated returns.

Payment for freeze-damaged cane is determined by applying to the standard cane payment, deductions based on the titrated acidity of the grower's juice samples.

The method for payment for cane in the event of a general freeze is similar to the Winter-Carp Method for salvage cane in which a processing cost is deducted from the calculated returns to arrive at the grower's payment.

Distribution of Returns

The considerations in annually setting the basis for cane payment are stated in the 1961 cane price determination:

> "Analysis of comparative returns, costs, and profits of producing and processing sugar cane obtained through field survey and recast in terms of prospective price and production conditions for the 1961 crop, indicates that the sharing relationship between producers and processors provided by the 1960 determination will also be equitable for the 1961 crop."[8]

These considerations are amplified in the section of the 1961 determination covering the Sugar Division's conclusions regarding a request by the Louisiana Farm Bureau Federation that the growers' participation in the molasses proceeds be increased.

[8] *Ibid.*, p. 13.

> "Comparative returns and cost data for producing and processing sugar cane reveal that during the past several years processing costs have changed in about the same proportion as have producing costs, and that under the present sharing relationship, the producers' share of returns is favorable compared to total costs. Thus to maintain an equitable sharing of total returns, a change in the sharing of the proceeds from molasses as recommended would need to be offset by a comparable change in the sharing of raw sugar returns. Accordingly the sharing relationship applicable to the 1960 crop has been continued."[9]

The comparative cost and returns data are derived from data collected by Sugar Division survey teams which make industry field studies every four years. In these field studies, annual economic data from selected survey factories and farms for a three year period are tabulated and collated.

MECHANICAL HARVESTING – ITS EFFECT ON CANE QUALITY AND CANE PAYMENT IN LOUISIANA

The Early Years

The period of World War II brought about drastic changes in the method of harvesting sugar cane. Shortage of field labor resulted initially in merely hand-cutting the cane top and bottom and subsequently in the rapid introduction of mechanical loading and mechanical harvesting. The practice of burning the cane after cutting and before loading

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[9] *Ibid.*, p. 15.

became standard in many areas. However, during rainy periods, burning was impossible and factories reported receiving cane carrying from five to twenty per cent trash.

Early studies were directed to determining the volume and quality of the trash accompanying the cane and the effect of the trash on the milling operation. Studies at Youngsville showed that as much as 35 per cent of cane cut at ground level consisted of unripe top joints and leaves attached to the top joints. Leaves attached to cane which was topped at the top ripe joint weighed from eight to fifteen per cent as much as the "clean mill cane" portion of the stalk (topped and all foliage removed).[10]

As early as 1939, milling tests were conducted at the Audubon Sugar Factory to determine the effect of trash on sucrose extraction. These studies were continued through the war years.[11, 12, 13]

In 1943, Arceneaux conducted detailed pilot scale experiments

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[10]M. V. Yarbrough, "Effects of Milling Cane Trash," The Sugar Bulletin, XXIV (1945), 33-35.

[11]T. Ben Arnold and Arthur G. Keller, "Sugar Milling Results – Audubon Sugar Factory Season 1941," The Sugar Bulletin, XX (1942), 156-161.

[12]J. C. Etheredge and H. C. Henry, "A Comparative Milling Test of Average and Trashy Cane," The Sugar Bulletin, XXI (1943), 89-91.

[13]Carl W. Stewart, "Sugar Research," The Sugar Bulletin, XXIII (1945), 125.

covering the effect of green and dry trash on milling results and the quantity and quality of non-sucrose solids in extracted juice due to different proportions of green and dry trash. In these studies, weighed amounts of green and dry trash were added to clean cane. The subsequent cane samples were repeatedly milled with maceration water in a sample mill in order to simulate commercial milling operations.[14] Studies of a similar nature were conducted by Balch and Broeg in 1947.[15]

Rather extensive studies were directed toward alleviating the trash problem. Yarbrough reported the following benefits for cane washing and subsequent soil removal at Youngsville Factory: (1) Improved furnace and boiler performance; (2) Lower filter press mud sucrose losses; (3) Increased clarification rates; (4) Reduced mill wear; and (5) Less mill slippage with subsequent higher milling rates.[16] Vought reported on the results with an experimental cane cleaning unit at the South Coast Corporation Terrebonne Factory. The unit consisted of a feeder carrier equipped with a guillotine knife which cut

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[14]George Arceneaux, "Some Effects of Trash in Cane on Milling Results," The Sugar Bulletin, XXII (1944), 151-158.

[15]R. T. Balch and C. B. Broeg, "The Sugar Cane Trash Problem from a Chemical Standpoint," Paper prepared for presentation at the Annual Meeting of the American Society of Sugar Cane Technologists, February 12, 1948.

[16]M. V. Yarbrough, "Washington Sugar Cane in Preparation for Milling," Proceedings American Society of Sugar Cane Technologists 1946-1950, (February, 1953), pp. 162-171.

the cane into short lengths, rotating drums to dislodge the trash from the cut cane, and blowers to remove the trash from the system.[17] Preliminary results at the Audubon Sugar Factory with a rotating cylindrical tumbler for trash removal were reported in 1945.[18] In 1951 tests were conducted at the Audubon Sugar Factory on cane which was mechanically harvested and cleaned in the field. The harvester, which was built by the Thompson Machinery Company of Thibodaux, Louisiana, was designed to cut, clean, and load the cane in a single operation.[19]

Daubert estimated the cost of trash to a factory grinding 100 – 125,000 tons of cane per crop to be about $100,000. This cost reflected lower grinding rates due to the additional fiber in the cane, loss in clarifier capacity, loss of sucrose in bagasse, filter press mud and undetermined losses, increased wear on machinery, and the cost of sampling for trash.[20]

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[17]F. A. Vought, "Cane Cleaning as Practiced in Louisiana," Papers Presented at Meetings of the American Society of Sugar Cane Technologists During the Years 1941-1945 Inclusive, (Houma, Louisiana, 1946), pp. 97-101.

[18]C. V. Fertitta, C. F. Walton, and Arthur G. Keller, "Sugar Cane Trash Investigation – 1945," L.S.U. Engineering Experiment Station Bulletin No. 9, pp. 15 and 16, and 24-26.

[19]R. H. Bianchi and Arthur G. Keller, "Clean, Fresh Cane – How Much Is It Worth?," L.S.U. Engineering Experiment Station Bulletin No. 28, (1952).

[20]W. S. Daubert, "The Cost of Trash to the Sugar Factory," Proceedings American Society of Sugar Cane Technologists 1946-50, (February, 1953), pp. 127-131.

During the 1943 through 1947 crops, the cane price determination permitted a trash tolerance of three per cent of the weight of the sugar cane delivered. Such trash deductions were, however, not mandatory. In the 1948 determination, the definition of standard cane was revised to provide mandatory weight deductions for trash in excess of three per cent. Recommended procedures for trash determination were published by the LSU Engineering Experiment Station in 1948.[21]

The Decline in Yield

By 1948 it was evident to the whole sugar industry that the yield of raw sugar as reported by the factories was declining at an alarming rate. In recognition of the problem, the American Sugar Cane League sponsored a study to investigate the cause of the declining yield. The subsequent study showed that the state average raw sugar yield had indeed reached an abnormally low level, and that the problem was compounded by the fact that the payment for cane to the growers was not reflecting the low yield level. The latter observation was attested to by a comparison by crop year of the actual state average yield with the theoretical yield at the state average normal juice sucrose level. The theoretical yield was determined from tables of commercially recoverable 96° raw sugar which were used to calculate the Sugar Act benefit

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[21]Arthur G. Keller, "The Determination of Trash in Sugar Cane," L.S.U. Engineering Experiment Station Circular No. 1, (1948).

payments. The theoretical yield gave in effect the average predicted recoverable sugar yield for a given quality of cane as delivered to the factory. Table II shows the annual state average yield of 96° raw sugar, the predicted yield, the yield deficiency (actual minus theoretical yield) and the percent of the returns for raw sugar which accrued to the state average grower and processor.[22]

A concurrent study by Arceneaux showed that the effect of variety change on the potential yield of sugar over the period of investigation was negligible and could in no way account for the yield decline.[23]

The yield deficiency could not be attributed to lowered factory efficiency occasioned by deterioration of equipment due to wartime restrictions. To the contrary, following the war, most of the factories in the state had followed a fairly extensive program of equipment modernization and replacement.[24] There was reason to believe that the high incidence of rainfall over the grinding season during the recent years had been a contributing factor to the low yield; but by itself, rainfall was not felt to be the major explanation for the yield deficiency.[25]

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[22] John J. Seip and Arthur G. Keller, "A Study of the Causes of the Declining Sugar Recovery in Louisiana," L.S.U. Engineering Experiment Station Bulletin No. 14, (1948), pp. 14 and 22.

[23] George Arceneaux, "Yield Trends in Tests of Sugar Cane Varieties and in Annual Production of Cane and Sugar in Louisiana," The Sugar Bulletin, XXVI (1948), 289-299.

[24] Seip and Keller, op. cit., p. 5.

[25] Ibid., pp. 1-3.

TABLE II

ACTUAL YIELD VERSUS THEORETICAL YIELD

AND DISTRIBUTION OF RETURNS FROM SUGAR

1938-1947

Year	Theoretical Yield-96° Raw Sugar, Lbs./Ton Cane	Actual Yield-96° Raw Sugar, Lbs./Ton Cane	Yield Deficiency-96° Raw Sugar, Lbs./Ton Cane*	% of Actual Sugar Growers	% of Actual Sugar Processors
1938	167.54	168.96	1.42	63.84	36.16
1939	172.66	173.50	0.84	64.06	35.94
1940	162.80	161.98	- 0.82	64.70	35.30
1941	164.44	165.28	0.84	64.05	35.95
1942	171.73	171.44	- 0.29	64.48	35.52
1943	168.64	164.06	- 4.58	66.17	33.83
1944	161.02	152.54	- 8.48	67.96	32.04
1945	160.11	151.37	- 8.74	68.09	31.91
1946	169.72	155.95	-13.77	70.06	29.94
1947	167.50	149.10	-18.40	69.35	30.65

*Yield Deficiency = Actual Yield Minus Theoretical Yield

In each factory studied, a definite trend toward yield decline was observed with an increasing use of mechanical harvesting. However, even correcting the yield to a net cane basis and adjusting for sucrose losses in bagasse due to trash did not satisfactorily approximate the predicted yield. That the yield deficiency lay in factors <u>other</u> than the effect of the gross weight of trash was acknowledged in the following comment:

> "Mills which receive preponderantly hand cut (60% or more), unburned cane had considerably lower yield deficiency values than did mills receiving preponderantly machine-harvested and burned cane. The first group showed much higher trash per cent cane than did the latter group. It would thus appear that freshness or staleness of cane is a factor of equal or greater import than trash. Because Louisiana cane can seldom be burned standing, the practice has developed fo allowing cut cane to lie in the field from one to several days for the leaves and trash to dry sufficiently to give a good burn. Without proper control, and few large growers appear to have such control, cane may deteriorate greatly during this period with consequent lowering of normal juice extraction and purity. Juice from freshly cut cane invariably clarifies better and works better in the boiling house than does juice from stale cane.
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> "It should be noted, however, that trash definitely lowers mill capacity to grind. None of the high trash, fresh cane mills were able to achieve the grinding rates (reduced to a comparable basis) of the mills grinding burned, relatively low-trash cane."[26]

In a subsequent review of the yield studies, Keller noted that the blame for poor cane quality must be shared by the factories since 43 per cent of the cane milled in Louisiana was owned by factory

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[26] <u>Ibid</u>., pp. 14-15.

interests. Data were compiled showing the cost of trash to the factories and the extent of benefit payments on trash. The necessity for aggressive coordination by the factories of the cane harvesting and milling operation to assure fresh cane was noted. It was recommended that no trash tolerance be permitted in cane payment. Mechanical grabs for trash sampling and provisions of mud guards on trucks, tractors, and cane carts were suggested.[27]

Prior to the 1948 cane price determination, trash deductions on cane received at the factory were voluntary. In the 1948 determination, standard cane was defined as cane with three per cent trash. Trash deductions above three per cent were mandatory. In order to encourage the delivery of clean fresh cane, the 1949 determination lowered the trash tolerance to one and one-half per cent, raised the sugar cane pricing factor to 1.045 from 1.030, and incorporated normal juice purity factors in the cane payment formula. In addition, the prevailing regional quality factors, which differed from area to area by virtue of the raw sugar freight rates, were eliminated and a single set of quality factors was adopted for the state. Differences in raw sugar freight rates were to be compensated for by adjustments to the base price of 96° raw sugar as used in computing the cane payment. In addition, standard sugar cane, which formerly was defined as sugar cane

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[27]Arthur G. Keller, "The Cane Trash Problem – A Possible Solution," The Sugar Bulletin, XXVII (1949), 220-230.

containing a stated range of sucrose in normal juice, was redefined at a single level of sucrose in normal juice and a stipulated purity range.

In the 1950 determinations, no trash tolerance was permitted, and the pricing factor was raised to 1.06. Standard sugar cane was based on net (trash free) cane. In addition, the cane samples were to be ground in the sample mill in the same condition as received in the cane delivery (before removing trash) rather than trash-free as in previous determinations. In this way it was felt that the sample quality would more correctly reflect the effects of the trash on the factory juice quality.

Subsequent Studies

Studies continued on the effect of trash on the milling operation as well as the benefits from improved harvesting and cane delivery practices which would result in fresh cane at the factory. A comprehensive study at the Audubon Sugar Factory in 1950 presented the effect of trash on mill power, sucrose extraction, and fiber in terms of one per cent trash in cane.[28] The operating advantages and economic savings for processing clean, fresh cane were further explored during the 1951 crop.[29]

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[28] Francis G. Schaffer and Arthur G. Keller, "The Effects of Cane Trash on The Milling Operation," L.S.U. Engineering Experiment Station Bulletin No. 25, (1951).

[29] Bianchi and Keller, op. cit.

The savings for fresh cane through prompt and well coordinated field to factory delivery were developed in a series of studies by Guilbeau, Coll, and Martin.[30,31,32] These studies pointed up the truisms that raw sugar is manufacturing in the field; that losses in the field through poor harvesting and delivery practices may greatly exceed those in the raw sugar factory; and that money and effort spent in reducing the "field" losses in many cases shows a significantly higher return in terms of raw sugar yield than an equivalent investment in the factory operation.

The need was recognized for informing – and reminding – the Louisiana cane farmer of proper harvesting practices to minimize the effects of trash and stale cane. For this purpose, the American Sugar Cane League has utilized its bi-weekly publication The Sugar Bulletin.[33,34]

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[30] W. F. Guilbeau, E. E. Coll, L. F. Martin, "Effect of Delay in Grinding on Value and Processing Quality of Sugar Cane Juice," The Sugar Journal, XVII (July, 1955), 28-31.

[31] ____________________, "The Value of Fresher Cane to Both Growers and Processors," The Sugar Bulletin, XXXIV (1956), 205-212.

[32] ____________________, "Fresher Cane Increases Sugar Recoveries and Profits for both Growers and Processors," The Sugar Bulletin, XXXVI (1958), 343-346.

[33] "In the Field with Lloyd Lauden," The Sugar Bulletin, XXXVI (1957), 20.

[34] "____________________," The Sugar Bulletin, XXXVI (1957), 52.

Despite the revisions which had been made to the system, there was ample evidence that the methods of sampling, testing, and evaluating sugar cane still did not adequately reflect the quality of cane harvested under mechanical conditions. Basic improvements in the methods of sugar cane quality determination were felt to be necessary. In outlining the scope of suggested improvements -- an outline which in effect laid the basis for subsequent cane sampling and evaluation studies at the Audubon Sugar Factory -- Keller commented upon the effects of the transition of the Louisiana sugar cane industry from an essentially manual-animal system of field operations to a completely mechanized operation:

> "Mechanization has been a mixed blessing. It has permitted the cane grower to bring about an enormous reduction in the man-hours of labor to produce a ton of sugar cane and to hold his production costs down to a point where the average farmer has been able to produce cane at a profit. --- Mechanization has been the excuse, too, for shoddy work in -- phases of the farming operations."[35]

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[35]Arthur G. Keller, "Mill Cane Quality and Its Improvement," Memorandum to the Louisiana Processors, (Ca. 1953), (Unpublished).

CHAPTER V

STUDIES OF CANE QUALITY DETERMINATION AT THE AUDUBON SUGAR FACTORY

From 1952 to 1959, the Chemical Engineering Department conducted at the Audubon Sugar Factory extensive studies on cane quality determination. Rather than present the individual studies in chronological form, they are presented in the order which appears in retrospect to offer a more or less logical development of the subject of cane quality determination.

Studies comparing the reproducibility of the methods of processing the cane samples are first discussed. The comparative reproducibility of the three-roll sample mill and the chipper-Waring blender is presented.

The next section covers the inherent variability of pol per cent cane and fiber per cent cane within a field of sugar cane and within a commercial bundle of cane entering the factory.

The effect of the size of the sample – or the number of stalks in the sample – on the precision of the sample is next discussed.

Studies of various commercial methods of withdrawing the sample from a shipment of cane are covered in the following section.

These methods include sampling by hand and by a hydraulically operated mechanical grab.

A device for removing a sample by coring through the bundle of sugar cane and the relative precision of this method of sampling as compared to the more conventional sampling methods are discussed.

The final section briefly covers investigations on the relative costs of different methods of withdrawing and processing the sample.

REPRODUCIBILITY OF THE THREE-ROLL SAMPLE MILL AND OF THE COLD WATER EXTRACTION PROCESS

Object and Equipment

In 1958, a study was made of the relative reproducibility of the two common methods of direct cane quality determination, i.e., the three-roll sample mill and the cold water extraction process. The three-roll sample mill used in these studies is a Farrel king-boltless unit equipped with 12 in. x 12 in. rollers grooved with 3/8 in. pitch at 50° angle – and an Edwards hydraulic system providing a maximum pressure of 40 tons on the top roll.

The equipment used in the cold water extraction process consisted of a cane chipper, a Y-type tumbler blender and a Waring blender. The chipper, which at full load operates at a speed of 1160 rpm, prepares the cane into chips which are approximately cubical in size of 1/4 in. to 3/4 in. per side. The chipped cane was mixed in a

Y-type tumbler blender, which rotates at 13 rpm and has a capacity of 40 gallons. The Waring blender consists of a stainless steel bowl of a rated capacity of one gallon, a water-tight lid to the bowl, and a motor mount for the bowl. Inside the bowl at the bottom is a gland packed shaft with two sets of short two-blade knives. The base of the shaft is constructed so that it interlocks with the drive shaft of the motor. The motor has four speeds ranging from 8,000 to 16,000 rpm at 2,000 rpm intervals.

Procedure -- The Split Cane Test

40 pound samples were withdrawn from a bundle of cane and detrashed. Each stalk in the sample was cut into sections of two to three feet length, and the sections split into halves. The halves were distributed into two sets of samples (Sample A and Sample B) which were to be subsequently processed through either the sample mill or the chipper-Waring blender. Each sample set was thoroughly mixed.

The milling test samples were weighed prior to processing to provide a material balance check against the weight of the products. Each sample was handled separately. The samples were laid in feed troughs constructed of galvanized iron. The troughs were of such dimensions that they fitted easily into the mill housing, and by tilting the troughs the cane fed by gravity into the feed roll of the mill. After passing once through the mill, the crushed cane was remilled to assure uniform extraction. The bagasse and juice were weighed, inspected, and the pol and fiber per cent cane and the purity of the extracted juice were calculated. Pol was determined by Horne's dry lead, Soluble solids were by hydrometer.

Samples A and B for the chipper-Waring blender were processed separately. The samples were chipped in the chipper, and the mass of chipped sample was placed in the Y-type tumbler-blender and mixed for 10 minutes. About 300 grams of the chipped sample were weighed out and mixed with 1000 ml. of water in the Waring blender - and the chips were digested for a period of 30 minutes at 8,000 rpm. The residue and extract were inspected, from which data the pol and fiber per cent cane and the purity of the extracted juice were determined.

Results

For purposes of this review, in order to show the relative precision of the three-roll sample mill and the chipper-Waring blender, the coefficients of variation for sucrose and fiber per cent have been calculated from the original data.[1] The results are shown below while the original data are presented in Table III:

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[1]Biraja Bilash Paul, "Evaluation of Commercial Deliveries of Sugar Cane," Ph.D. Dissertation, in the Department of Chemical Engineering, Louisiana State University, (August, 1960), p. 182.

TABLE III

PRECISION OF THE THREE-ROLL SAMPLE MILL VERSUS THE COLD WATER EXTRACTION PROCESS

(SPLIT CANE TESTS)

	Pol % Cane				Fiber % Cane			
	3-Roll Sample Mill		Cold Water Extraction		3-Roll Sample Mill		Cold Water Extraction	
Run No.	A	B	A	B	A	B	A	B
1	8.85	8.89	10.02	9.05	13.37	13.30	13.90	13.10
2	8.74	8.73	7.58	7.72	13.60	13.78	15.70	14.50
3	8.96	8.97	9.07	8.96	14.41	14.55	13.20	13.40
4	8.78	8.95	9.22	9.44	13.84	14.52	12.90	12.83
5	8.72	8.66	8.38	8.11	14.67	14.92	14.07	13.67
6	9.52	9.34	9.23	9.32	14.50	16.04	13.80	13.60
7	8.61	8.50	8.19	8.38	16.68	16.85	13.67	12.87

	Coefficient of Variation, % (Split Cane Test)	
	Three-Roll Sample Mill	Chipper-Waring Blender
Pol % Cane	1.29	4.98
Fiber % Cane	5.17	4.44

Comments

Coefficients of variation for pol per cent cane of 1.48 per cent and for fiber of 1.46 per cent were reported in South Africa for the cold water extraction process.[2] A coefficient of variation of 2.3 per cent for pol per cent cane was reported in Hawaii.[3] Compared to these data, the cold water extraction process in the LSU studies with a coefficient of variation of 4.98 per cent for pol and 4.44 per cent for fiber showed considerably less precision than might be expected.

The coefficient of variation for pol per cent cane of 1.29 per cent showed very good reproducibility for the three-roll sample mill with respect to this criterion of cane quality.

The coefficient of variation for fiber per cent cane of 5.17 per cent with the sample mill is not too satisfactory. If the paired data for

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[2] K. Douwes Dekker, "A Survey of the Work done in S.A. on the Direct Analysis of Cane Consignments," Sugar Milling Research Institute, Quarterly Bulletin No. 7, (August, 1958), pp. 23-25.

[3] John H. Payne and Henry J. Mahon, "The Pol Ratio Method of Evaluating Cane Quality," Proceedings of the Ninth Congress of the International Society of Sugar Cane Technologists, (1956), p. 444.

Run No. 6 with the sample mill and Run No. 2 for the chipper-Waring blender are eliminated because of very poor agreement between pairs, the coefficient of variation for fiber per cent cane becomes 2.38 per cent for the three-roll sample mill and 2.67 per cent for the chipper-Waring blender. This effects a considerable improvement in precision.

Regarding the reproducibility of the laboratory procedure in making the product inspections, it is interesting to note the relative extent of agreement of paired data from duplicate pol and fiber inspections of the same samples. Among Paul's studies were duplicate inspections of the products from the three-roll sample mill and the chipper-Waring blender covering 10 runs.[4] These data have been reworked to determine the coefficients of variation for pol per cent cane and fiber per cent cane as the coefficients reflect the precision of the laboratory inspections. The results are as follows:

	Coefficient of Variation (From Duplicate Laboratory) (Inspections of the Same Products)	
	Three-Roll Sample Mill	Chipper-Waring Blender
Pol % Cane	0.28	1.71
Fiber % Cane	2.60	2.45

[4]Biraja Bilash Paul, "Sampling of Commercial Deliveries of Sugar Cane - A Comparative Study," M. S. Thesis in the Department of Chemical Engineering, Louisiana State University, (June, 1958), p. 72.

These data show excellent reproducibility for the pol inspections of the juice and bagasse from the three-roll sample mill. In the case of fiber per cent cane, these data show an inherent lack of reproducibility in the methods of determining fiber in bagasse from the sample mill and in the residue from the Waring blender.

In an effort to improve the precision of the chipper-Waring blender method, the studies were extended to cover the effect of blending time and the size of the chips. The lack of uniformity in chip size led Paul to the hypothesis that the smaller chips – because of the greater incidence of ruptured juice cells – were losing juice to the walls of the tumbler.[5] Because of the length of time involved in preparing the cane for the Waring blender and in the subsequent laboratory operation with the blender, no further research work on the chipper-Waring blender was felt to be justified.[6]

THE INHERENT VARIATION IN SUGAR CANE QUALITY IN THE FIELD AND IN A COMMERCIAL BUNDLE

Objective

One need spend only a limited time of study on cane sampling before becoming aware of the wide variation in cane quality from stalk

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[5] *Ibid.*, pp. 73-79.

[6] Paul, "Evaluation of Commercial Deliveries of Sugar Cane," p. 104.

to stalk and from sample to sample within a shipment of cane. This is in addition to the acknowledged variation in cane quality from top to bottom within a single stalk of cane. Under such circumstances it is desirable to define the extent of quality variation inherent in the cane as delivered to the factory.

During the 1959 crop, studies were conducted to determine the variation of cane quality within (1) a field plot of cane of sufficient size to yield a commercial bundle of cane, and (2) a commercial bundle of cane delivered to the factory.[7] (In Louisiana, the commercial bundle of cane weighs from 2-1/2 to 3-1/2 tons).

Procedure

Sugar Cane Plot

1. A total of ten plots of cane - all of the same variety and of uniform growth - were selected from the fields of the Louisiana State University Agricultural Experiment Station, the Louisiana State Penal Farm at St. Gabriel, Louisiana, and Catherine Sugar Factory at Lobdell, Louisiana.
2. Each plot was divided into 100 subdivisions and by a table of random numbers, ten sub-plots were selected.

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[7]Shwen-ih Wang, "Variance of Cane Quality - A Comparative Study," M.S. Thesis in the Department of Chemical Engineering, Louisiana State University, (June, 1960).

3. A sample consisting of ten stalks of cane was removed from each sub-plot, cleaned of tops and trash, and identified with a sub-plot number.

4. Each 10-stalk sub-plot sample was weighed and passed twice through the three-roll sample mill. The juice and bagasse were collected, weighed and analyzed.

5. From the juice and bagasse weights and inspections, the pol and fiber per cent cane and the extracted juice purity were determined.

6. For each plot, the pol and fiber per cent cane and the extracted juice purity of the ten sub-plot samples were tabulated. The subsequent data for the 10 plots were statistically analzyed.

Sugar Cane Bundle

1. Six commercial bundles of sugar cane, which were delivered to the Audubon Sugar Factory, were analyzed. Each bundle was opened and the number of stalks counted. For every 100 stalks, the first five stalks were taken as a sample. Since the bundles contained 2500 to 3000 stalks, 25 to 30 samples were removed from each bundle.

2. Each five-stalk sample was weighed and passed twice

through the sample mill. Juice and bagasse were collected, weighed and analyzed.

3. From the juice and bagasse weights and inspections, the pol and fiber per cent cane and the extracted juice purity were determined.

4. For each bundle, the pol and fiber per cent cane and the extracted juice purity of the five stalk samples were tabulated. The subsequent data for the six bundles were statistically analyzed.

The pol and fiber per cent cane and the purity of the extracted juice for each plot were assumed to be the average of the 10 sample inspections. In the same manner, the quality of each commercial bundle was assumed to be the average of the 25 to 31 inspections for each bundle.

Results

The average coefficient of variation for pol and for fiber per cent cane for the field plot and for the bundle studies – and the range of coefficients are shown below:

	Coefficient of Variation For One Sample, %			
	Plot		Bundle	
	(Samples of 10 stalks per plot or about 10.0% of the total cane sampled)		(Samples of 5 stalks per bundle or about 3.4% of the total cane sampled.[8])	
	Average	Range	Average	Range
Pol % Cane	4.36	2.33 - 6.61	5.85	1.07 - 10.26
Fiber % Cane	7.50	5.05 - 10.58	5.09	3.20 - 7.47

In both the field and the bundle studies, a wide variation in the pol and the fiber content was noted. For example, in Bundle No. 1, the 29 samples of five stalks each ranged from 9.58 to 11.87 pol per cent cane and 9.53 to 12.95 fiber per cent cane. For pol, the coefficient of variation was 5.97 per cent and for fiber 7.47 per cent. For pol, the 95 per cent confidence limits of one five-stalk sample were 9.33 to 11.85 pol per cent cane, and for fiber 9.77 to 13.22 fiber per cent cane.

Comments

The fact that the bundle samples showed a wider variation in pol from sample to sample is probably due to several factors; among

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[8]The total cane sampled is assumed to be only the cane actually ground in the sample mill. Thus in the plot studies, ten - 10 stalk samples were ground for each plot. So each 10 stalk sample represented 10 per cent of the total cane.

them are: (1) Each five-stalk bundle sample represented only about 3.4 per cent of the total cane actually sampled in the bundle studies, while each 10-stalk sample was ten per cent of the total cane sampled in the plot studies; (2) The bundles sampled were taken at the beginning of the crop and immature cane may show a wider variation in quality than mature cane; and finally (3) While the plot samples were topped and destrashed prior to grinding, there is no record that the bundle samples were so prepared. It appears that they were ground as removed from the bundle.

To provide a "feel" for the typical variation in pol per cent cane which might be expected from five-stalk sample to five-stalk sample in a commercial bundle of cane entering a factory, the data on Bundle No. 1 are reproduced in Table IV.[9]

From the data of these studies it is possible to <u>predict</u> the beneficial results of increasing the number of stalks in a sample. Tabulated below are the <u>predicted</u> coefficients of variation and 95 per cent confidence limits when drawing a 10 and a 15-stalk sample as compared to a five-stalk sample in Bundle No. 1.

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[9] *Ibid.*, p. 58.

Number of Stalks in Sample	% of Total Stalks Sampled	Coefficient of Variation, %	95% Conf. Limits of One Sample, Pol % Cane
5	3.4	5.97	9.33 - 11.85
10	6.9	4.25	9.68 - 11.50
15	10.3	3.44	9.82 - 11.36

SIZE OF SAMPLE VERSUS PRECISION OF THE CANE QUALITY TESTS[10]

Objective

The studies in this section are cited as an example of investigations to show the actual effect of the sample size - or the number of the stalks - on the precision of the tests for pol and fiber in cane. The original purpose of these studies was to provide a rapid means of analyzing the milling response of new varieties of sugar cane. The conventional method of testing new varieties at the Audubon Sugar Factory consisted of grinding on the factory mill tandem at least two tons of cane - for a single test - and up to four to eight tons for replicate tests. This procedure was time consuming and delayed the

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[10]Willem Melis and Arthur G. Keller, "Evaluation of Sugar Cane Varieties - A Comparison of Testing Procedures - 1952 and 1953 Studies," A Report of work done under contract with the United States Department of Agriculture and authorized by the Research and Marketing Act of 1946, Louisiana State University (1953). (Unpublished).

TABLE IV

VARIATION IN POL PER CENT CANE

OF SAMPLES FROM

A COMMERCIAL BUNDLE OF SUGAR CANE

POL % CANE

Basis: One 5-stalk sample removed every 100 stalks of cane in the bundle.

Bundle No.	Date	SAMPLE NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	10/24/59	10.31	9.99	11.37	9.69	9.58	10.29	11.19	10.87	10.23	9.95	10.18	10.22	11.83	10.47	11.70	11.87
2	10/31/59	10.65	11.05	10.71	10.54	11.15	10.53	10.25	11.58	11.78	11.56	11.11	11.84	11.26	10.46	11.10	10.29
3	11/7/59	9.45	10.05	9.85	9.94	10.65	10.13	10.20	10.09	10.05	10.07	10.69	9.90	10.90	10.14	10.35	10.54
4	11/14/59	11.27	10.91	10.46	9.86	10.92	8.82	10.74	10.05	9.88	9.98	10.06	8.11	8.64	9.56	10.73	8.82
5	11/21/59	9.59	8.97	10.90	8.98	9.85	9.64	10.18	9.95	9.84	10.18	9.07	8.54	9.67	9.27	8.34	9.05
6	12/7/59	8.31	8.69	8.12	7.33	7.43	7.45	7.41	7.37	7.72	8.40	7.88	7.74	8.20	8.12	8.56	7.26

Bundle No.	Date	SAMPLE NUMBER 17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Avg.
1	10/24/59	10.95	10.09	10.42	10.14	10.46	9.84	10.41	11.17	11.01	10.28	10.80	10.49	11.39	-	-	10.59
2	10/31/59	9.59	10.55	10.59	11.03	10.88	10.79	10.23	10.99	9.70	11.09	11.01	9.62	11.32	10.27	10.35	10.77
3	11/ 7/59	9.99	10.64	10.66	10.18	10.17	10.71	10.60	10.15	-	-	-	-	-	-	-	10.25
4	11/14/59	10.18	8.84	8.51	8.49	8.44	8.40	9.16	9.96	-	-	-	-	-	-	-	9.57
5	11/21/59	9.63	9.03	9.61	8.53	8.84	9.29	8.30	9.87	9.38	-	-	-	-	-	-	9.38
6	12/ 7/59	8.65	8.48	8.69	8.32	7.98	8.05	9.09	7.33	8.68	8.15	7.91	8.66	8.37	-	-	8.08

release of new varieties. It was hoped to provide a milling procedure requiring only about 100 pounds of sample which would be processed on a three-roll sample mill, thus permitting more rapid evaluation and earlier testing of new varieties. Specifically, the 1952-1953 studies were directed to:

1. Developing a milling procedure for small test samples which would yield statistically reliable results.
2. Determining the minimum size test sample which would be necessary to give a reliable estimate of the pol and fiber in a commercial shipment of cane.

Procedure

Method of Collecting the Sample:

The sampling system consisted of counting the stalks and removing a stalk at specified intervals, i.e., for a one per cent sample, one stalk was set aside for every 100 stalks, and the stalks were composited to make a sample. Samples were collected in this manner over the range of 1/4 to 5 per cent of the shipment.

Method of Sample Preparation:

In both the 1952 and 1953 studies, the stalks were cut into pieces 8 to 12 inches long and thoroughly mixed. During the first half of the 1952 crop, the pieces were ground directly. However, during the latter half of the crop and during the whole of the 1953 crop, the pieces were shredded in a small swing-hammer mill in the expectation that a more uniform feed to the sample mill would result. The shredder was a Jeffery 15 in. x 18 in. Junior Pulverizer, driven at 2200 rpm by a 10 HP motor.

Processing the Sample:

When handling cane prepared with the shredder, the cane was spread to a uniform depth and density in galvanized troughs which were 12 inches wide, 6 inches deep and approximately 60 inches long. The troughs were the same width as the mill rollers so that by tilting the trough the feed entered the mill by gravity. Each sample was weighed and ground twice in the sample mill.[11] Juice and bagasse were analyzed. From the juice and bagasse weights and inspections the pol and fiber per cent cane of the sample were determined. After the samples were removed from the bundle, the remainder of the cane was weighed and ground on the large mill. From the product weights and inspections, the pol and fiber per cent cane of the actual shipment were determined:

Statistical Handling of the Data:

For each size sample, the relationship between the pol and

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[11]The Louisiana State University Agricultural Experiment Station three-roll sample mill was used for these studies. The studies cite for the mill a hydraulic load on the top mill of 25 tons and a mill speed of 6 rpm.

fiber per cent cane of the sample and the big mill was developed through linear regression of the data for all runs for the particular sample size. Such a relation - or correlation - could be expressed in the following form:

$$\hat{y} = a + bx$$

where: $\hat{y}$ is the estimated big mill inspection, i.e., pol per cent cane or fiber per cent cane.

x is the observed sample mill inspection, i.e., pol per cent cane or fiber per cent cane.

a is the intercept and b the slope of the line (the regression coefficient) which are developed through a regression analysis of the observed paired data for all the runs for each sample size.

Having developed such a correlation, it is then possible to predict the quality of a shipment of cane from an analysis of a sample from the shipment.

In the 1952 - 1953 studies, the degree of the association between the sample and the big mill results - as expressed by the linear correlation - was determined by means of the correlation coefficient, r. A comparison of the r values for different size samples thus gives a measure of the relative precision of each size samples. (The correlation coefficient squared, r^2, may be recognized as expressing the fraction of the sum of the squares of deviation which is removed by the correlation and is a measure of the goodness of the correlation.)

The memorandum covering the studies shows only the correlation coefficients for pol per cent cane and for fiber per cent cane for each size sample and not the linear correlations themselves.

Results

The results of the 1952 and 1953 studies are summarized below in terms of the correlation coefficient — or the degree of correlation with the big mill results — for different size samples:

	Correlation Coefficient, r					
	Pol % Cane			Fiber % Cane		
Size of Sample, per cent of Total Bundle	Un-Shredded Cane 1952	Shredded Cane 1952	Shredded Cane 1953	Un-Shredded Cane 1952	Shredded Cane 1952	Shredded Cane 1953
5.00	—	—	0.9078[12]	—	—	0.7460
2.00	0.9490	—	—	0.7517	—	—
1.00	0.9470	0.8035	0.8715	0.4794	0.5200[12]	0.4894
0.50	0.9295	0.8854	0.8676	0.5829	0.6390	0.3333
0.25	—	0.8500	—	—	0.5433	—

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[12]The values of 0.9078 and 0.5200 were determined by recalculating the tabulated data from the 1952–1953 Studies. The original correlation coefficients of 0.9643 and 0.7160 are apparently in error.

Comments

For pol per cent cane, the studies showed no significant increase in the precision of sampling with a corresponding increase in the sample size. In the case of fiber per cent cane however, there is a perceptible increase in the sampling precision for the 2 per cent and the 5 per cent samples compared with the smaller samples. However, the best correlation coefficient of 0.75 appears to be far short of a satisfactory precision.

The reason for the failure of the pol samples to show a relationship between size of sample and precision of sampling is not clear. Perhaps the sample mill which was used for the studies did not give the reproducibility in milling which was obtained with the newer three-roll unit used in later studies at the Audubon Sugar Factory. It is probably significant that the two largest samples, i.e., the two per cent and the five per cent samples, each gave the best correlation of the particular run series, although the difference between the coefficients in each of the series is not pronounced.

To provide a "tie" between the correlation coefficient and a coefficient of variation for the correlation, coefficients of variation were calculated from the 1952 unshredded cane tests. The coefficients for this purpose were determined by dividing the standard deviation of the estimate, $s\,(\hat{y})$, by the average value of the big mill inspections, $\bar{y}$. The correlation coefficients and the corresponding coefficients of variation are shown below:

Size of Sample, % of Total Bundle	Pol % Cane: Correlation Coefficient r	Pol % Cane: Coefficient of Variation, %	Fiber % Cane: Correlation Coefficient r	Fiber % Cane: Coefficient of Variation, %
2.00	0.9490	5.68	0.7517	8.03
1.00	0.9470	5.77	0.4794	10.61
0.50	0.9295	6.63	0.5829	9.79

COMMERCIAL METHODS OF SAMPLING SUGAR CANE AND THEIR ACCURACY AND PRECISION

Object

From 1956 through 1958, studies were conducted to determine the accuracy and precision of various commercially feasible methods of sampling sugar cane. These cane sampling studies were the object of investigations by student groups in 1956, 1957, and 1958,[13, 14, 15,] as well as forming the basis for two graduate research projects.[16, 17]

Methods of Sampling:

The methods of sampling which were investigated fell under the following major classifications:

Simple Hand Sample: 2 to 10 stalks of cane were removed at random from the opened bundle. The number of stalks

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[13]"Cane Sampling Studies - 1956," A student group reserach project included in the course Chemical Engineering No. 161, Chemical Engineering Practice Laboratory, (Unpublished).

[14]"Cane Sampling Studies - 1957," A student group research project included in the course Chemical Engineering No. 161, Chemical Engineering Practice Laboratory. (Unpublished). The procedure, data, and results were published in "Progress Report No. 1 - A Study of Sampling and Methods of Determining Sucrose, Purity, and Fiber Content of Sugar Cane - 1957 Crop Operation," A report of work done under Contract No. 12-25-010-558 with the United States Department of Agriculture, (June, 1958), Appendix E.

[15]"Cane Sampling Studies - 1958," A student group research project included in the course Chemical Engineering No. 161, Chemical Engineering Practice Laboratory, (Unpublished). The data from these studies were published in "Final Report - A Study of Sampling and Methods of Determining Sucrose, Purity, and Fiber Content of Sugar Cane," A report of work done under Contract No. 12-25-010-558 with the United States Department of Agriculture, (October 7, 1959), Exhibit IV.

[16]Paul, "Sampling of Commercial Deliveries of Sugar Cane - A Comparative Study."

[17]Paul, "Evaluation of Commercial Deliveries of Sugar Cane."

to be removed was specified for the test series.

Multiple Hand Sample: The opened bundle was considered to consist of eigh quadrants (four quadrants on each end). Two to three stalks of cane were removed from each quadrant and composited. In later studies, the center section of each end of the bundle was included in the sampling, thus giving eight quadrants and two center sections. The number of stalks to be removed was specified for the test series.

Simple Mechanical Grab: From the opened bundle, a single 20 to 30 pound sample was removed by a hydraulically operated mechanical grab. The approximate size of the sample was specified for the run series.

Multiple Mechanical Grab: Two to three 15 to 40 pound mechanical grab samples were removed from the opened bundle of cane. The number of the samples and the approximate size of the sample were specified for the test series.

Procedure

The samples were processed through both the new Farrel three-roll sample mill and the chipper-Waring blender. To accomplish this, samples of twice the size stated above were removed from the bundle and separated into two parts for subsequent processing. The samples were processed in the manner described in the preceeding section covering the comparative reproducibility of the three-roll sample mill and the cold water extraction process. After the samples had been removed, the remaining cane was processed in the big mill. The sample and the big mill results were compared in terms of the sucrose per cent cane, the fiber per cent cane, and the purity of the extracted juice.[18]

Statistical Handling of the Data:

The pol per cent cane and the fiber per cent cane of the sample were compared with the corresponding data for the big mill in terms of the accuracy and the precision of the sampling method. The accuracy was measured in terms of the average difference between the sample and the big mill data for all runs. (This difference – if consistent – is in effect the bias of the sampling method.) The precision was measured in terms of the estimated standard deviation of the individual differences, i.e., the differences between the individual sample

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[18]The methods of processing the samples and of conducting the concurrent big mill tests are covered in "Progress Report No. 1 – A Study of Sampling and Methods of Determining Sucrose, Purity, and Fiber Content of Sugar Cane – 1957 Crop Operation," A report of work done under Contract No. 12-25-010-558 with the United States Department of Agriculture, (June, 1958), Appendices C and D.

results and the corresponding big mill results. (This is in effect a measure of the degree of scatter of the individual differences about the mean difference).

Results

Measured in terms of the precision of the sampling method, the data from the earlier studies showed considerable variation. For pol, the estimated standard deviation of the difference ranged from 0.57 to 1.57 pol per cent cane, and the coefficient of variation, which was calculated from the standard deviation,[19] ranged from 5.43 to 14.4 per cent. For fiber the corresponding data were 0.76 to 2.37 fiber per cent cane and 5.7 to 17.8 per cent. No consistent differences in the precision of the various sampling methods were evident.

Paul's 1958 studies which were based on a review of the possible sources of error in the previous investigations, showed the most promising results -- in terms of precision -- of any of the sampling studies. In this test series, simple hand samples of 10 stalks per bundle were compared with a simple mechanical grab of 30 pounds and a multiple mechanical grab of two 15 pound samples. The data from

[19]The coefficient of variation was calculated from the original data for the purpose of this review. Since the coefficient is based on the standard deviation of the difference in this calculation, it does not reflect the average difference or bias between the big mill and the sample.

these 1958 studies are summarized in Table V.[20] Analyzing the data from the three-roll sample mill in terms of the precision of the sampling method it is noted that for pol per cent cane the mechanical grab is superior to the simple hand sample – and the multiple mechanical grab appears to be more precise than the simple mechanical grab. For fiber per cent cane, the method of sampling appears to have no effect on the precision of the sample. In comparing the chipper-Waring blender with the three-roll sample mill, it appears that the three-roll sample mill is more precise for pol per cent cane and both methods of sampling show about the same precision for fiber per cent cane.

Comments

It is rather difficult to evaluate a statistical analysis in which both the accuracy – or average difference of the sample from the big mill – and the precision – or measure of scatter – must be considered. In the above discussion of Paul's 1958 studies, only the precision was considered. Obviously, one method of sampling may show a large mean difference – or bias – but exhibit a high degree of precision. On the

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[20]The data in Table V are taken from "Final Report – A Study of Sampling and Methods of Determining Sucrose, Purity, and Fiber Content of Sugar Cane," A report of work done under Contract No. 12-25-010-558 with the United States Department of Agriculture, (October 7, 1959), pp. 46 and 49. The coefficients of variation, which are shown in this table, were calculated for the purpose of this review from the standard deviations of the difference. As such, they do not reflect the average difference between the big mill and the sample – only the precision of the sampling.

TABLE V

ACCURACY AND PRECISION OF

COMMERCIAL METHODS OF SAMPLING SUGAR CANE

1958 Studies (28 Runs)

	Pol % Cane			Fiber, % Cane		
Method Method of Sampling	Average Difference Big Mill Minus Sample, Pol % Cane	Standard Deviation of the Difference, Pol % Cane	Coefficient of Variation %	Average Difference Big Mill Minus Sample, Fiber % Cane	Standard Deviation of the Difference, Fiber % Cane	Coefficient of Variation %
			Three-Roll Sample Mill			
Simple Hand	-0.74	0.64	5.54	+1.68	0.92	6.44
Simple Mech. Grab	-0.24	0.45	3.90	+1.60	0.92	6.44
Multiple Mech. Grab	-0.30	0.39	3.38	+1.21	0.85	5.95
			Chipper-Waring Blender			
Simple Hand	–	–	Not Run	–	–	–
Simple Mech. Grab	+0.17	0.60	5.20	+1.84	1.04	7.28
Multiple Mech. Grab	+0.12	0.55	4.77	+1.63	0.78	5.46

other hand, a sampling procedure could average very closely the big mill results but show a high degree of scatter. An alternative statistical method would be to derive a correlation between the sample results and those of the big mill. In this manner, the average difference – or bias – can be removed, and only the precision need be studied. Along this line, the 1958 data for pol per cent cane have been recalculated in terms of a linear correlation relating the big mill data to that of the sample. This method of data handling was discussed in the preceding section SIZE OF SAMPLE VERSUS PRECISION OF THE CANE QUALITY TESTS. From such a correlation, which was derived through a regression analysis, the correlation coefficient, r, has been determined. In addition, the correlation coefficient squared, r^2, was calculated. r^2 is the fraction of the sum of the squares which is removed by the correlation. Finally the coefficient of variation was determined by dividing the standard deviation of the estimate, $s(\hat{y})$, by the average big mill value, $\bar{y}$. The results of this method of statistical handling are shown below.

Pol % Cane
Three-Roll Sample Mill

Method of Sampling	r	r^2	Coefficient of Variation, %
Simple Hand	0.69	0.48	7.75
Simple Mechanical Grab	0.81	0.66	6.77
Multiple Mechanical Grab	0.84	0.71	5.61

These data show the mechanical grab to be decidedly superior to the sample hand method of sampling for sucrose per cent cane.

While Paul's 1958 studies were encouraging, the precision of the various sampling methods appears to be still less than desired. The best coefficient of variation of five to six per cent for the multiple mechanical grab method of sampling represents 95 per cent confidence limits for one sample of about 10 to 12 per cent. This is a fairly large order of magnitude. By comparison, it will be recalled that the coefficient of variation representing the reproducibility of the three-roll sample mill was determined to be about 1.3 per cent. The corresponding 95 per cent confidence limits would approximate 3.0 per cent.

In speculating upon means to improve the precision of the sampling method, it is noted that the largest samples, i.e., the simple 30 pound mechanical grab and the two 15 pound multiple mechanical grabs, represented only about one per cent of the total cane delivery. It will be recalled that from the studies on the size of the sample versus the precision of the quality tests, it was deduced that reasonably consistent precision might be expected with two to five per cent samples. Hence by increasing the size of the samples in the studies of commercial sampling methods, the precision of the methods might have been increased.

One other source of error not mentioned so far is the accuracy of the big mill data. Obviously, any error in the big mill material balance or product inspections would be reflected in a lower degree of correlation for all sampling methods. In the subsequent studies which form the basis for this dissertation, the size of the big mill throughput was increased to minimize the effect of inherent limitations in the product weighing equipment at low volume throughput. Unfortunately, a larger mill throughput necessitated a larger volume of sample. The size of the sample handling equipment ultimately limited the size of the sample.

SAMPLING BY CORING

Object

During the 1957 grinding season, studies were initiated on a device for removing a core through a full bundle of cane. The advantage of such a sampling device was felt to be the ability to remove a completely representative sample of a cane consignment – including trash, soil, and any other extraneous material. In this manner, the human error in selecting a sample would be eliminated.

Equipment and Procedure[21]

Numerous modifications to the coring device were made during

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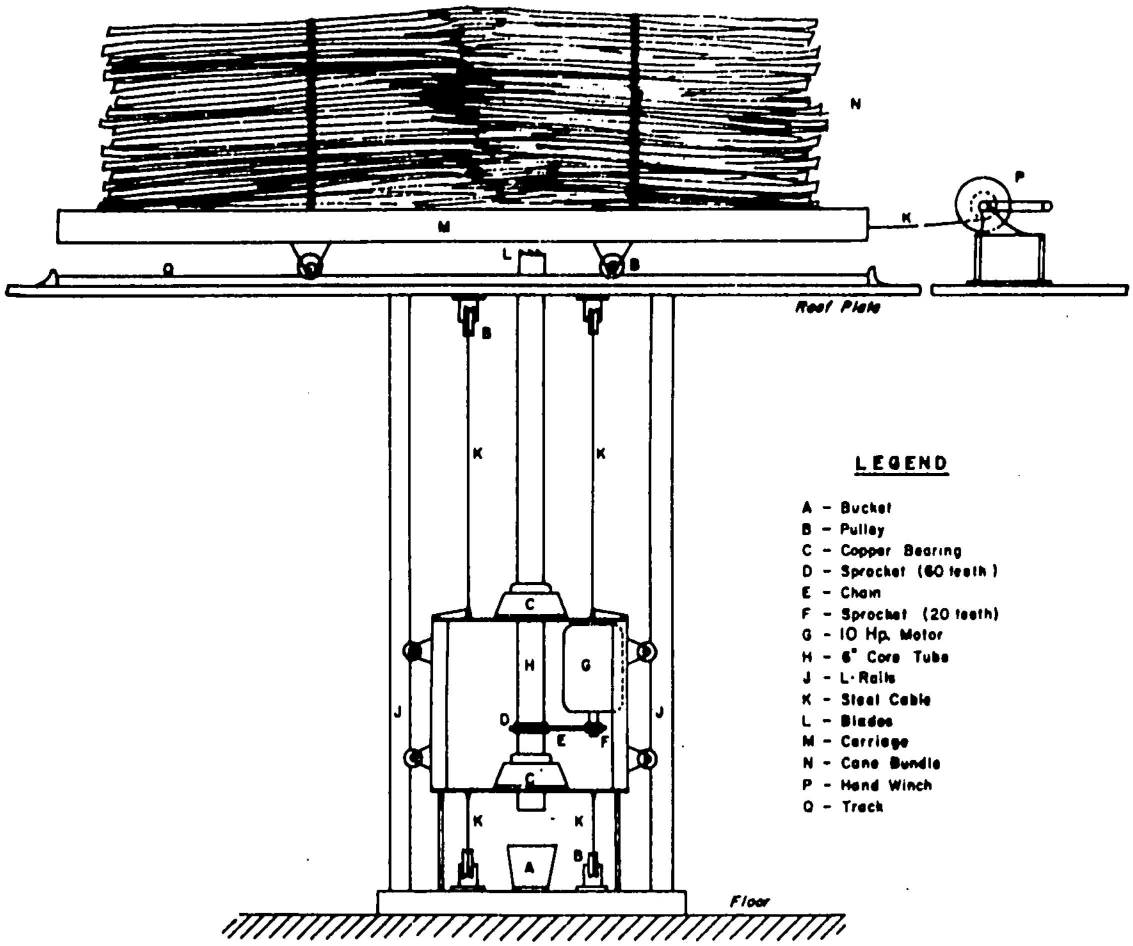
[21] Mechanical details of the corer are shown in the Appendix to "Progress Report No. 2 – A Study of Sampling and Methods of Determining Sucrose, Purity, and Fiber Content of Sugar Cane," A report of work done under Contract No. 12-25-010-558 with the United States Department of Agriculture.

test work covering the 1957, 1958, and 1959 crops. The final design is shown in Illustration 1. The coring machine consists of a 6" diameter tube eight feet in length (H) and rotating at 200 rpm. The end of the tube is serrated, and the edges of the serrations are hardened and sharpened to provide a cutting edge. A vertical 10 HP motor (G) (900 rpm) drives the 6 inch tube through a chain (E) and sprocket drive (F and D). The sprockets provide a speed reduction to the tube.

The bundle of cane to be tested is mounted on the carriage (M). With the hand winch (P) the carriage is positioned on the track (O) to permit coring the bundle at the desired point along its length. The electric motor is started and the coring machine is raised by the cable and pulley arrangement (B and K) to provide coring through the entire depth of the cane bundle. The core sample, which weighs three to six pounds, is collected in the bucket (A). After the core is withdrawn, the coring machine is lowered to its rest position. By moving the carriage on the track, cores can be removed at different positions along the length of the bundle.

In the 1957 through 1959 studies, the core samples were spread out lengthwise in the feed troughs for the three-roll sample mill and processed twice through the mill. The juice and bagasse were weighed and inspected, and from these data the - pol and fiber per cent cane and the extracted juice purity were determined.



CORE SAMPLER

Illustration 1

Results

In 1958, tests were conducted to locate specific positions along the length of the bundle where a core sample would adequately represent the entire bundle.[22] In these tests, cores were removed from six positions spaced at two feet intervals along the length of the bundle. These studies showed no significant difference in cane quality among the various coring positions. This was not entirely unexpected since the cane for these tests was manually cut and randomly loaded.

In a later series of tests, core samples were removed from positions near each of the two chains on the bundle.[23] These two positions were selected because the respective core samples contained 80 to 120 small pieces of cane – an appreciably larger quantity of individual cane pieces than from any other position in the bundle. The average of the inspections of the two core samples was taken as representative of the bundle.

Comments

The studies of the variation in the quality of six core samples along the length of the bundle were conducted during the latter part of the 1958 crop. During this period, the samples were removed daily

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[22] J. N. Goel, "Evaluation of a New Method of Sampling Sugar Cane Deliveries," M.S. Thesis in the Department of Chemical Engineering, Louisiana State University, (June, 1959).

[23] Paul, "Evaluation of Commercial Deliveries of Sugar Cane," p. 109.

from the same bundle of cane with which Paul was making his study of commercial sampling methods. This fact makes possible a comparison of the coring method with the simple hand, the simple mechanical grab, and the multiple mechanical grab during the latter 16 runs of the 1958 crop. This comparison has been made for purposes of this review for pol per cent cane. The core sample quality is assumed to be the average of the six core positions. A linear correlation is assumed between the quality of the core sample and that of the big mill, and the corresponding correlation coefficient has been determined. This is compared with the correlation coefficients for the other sampling methods over the same period as shown below:[24]

Sampling Method	Pol % Cane Correlation Coefficient, r
Simple Hand	0.49
Simple Mechanical Grab	0.80
Multiple Mechanical Grab	0.75
Core (Average of Six Cores)	0.83

These studies indicate that the coring method compared very favorably with the mechanical grab. Whether the difference in

[24]The sample and big mill data from which the correlation coefficients were calculated are shown on pages 167, 168, and 179 of Paul's Ph.D dissertation "Evaluation of Commercial Deliveries of Sugar Cane."

correlation coefficient of 0.83 for coring and 0.80 for the simple mechanical grab is indicative of the superiority of coring could only be proved by further tests. Interestingly enough, in these latter runs of Paul's studies, the simple mechanical grab shows up better than the multiple mechanical grab. For the total series of 28 runs, the reverse was true.

COMPARATIVE COSTS OF SAMPLING AND PROCESSING THE SAMPLES

During the 1957 crop, man-hour data and labor and equipment cost for sampling and processing the samples at representative Louisiana raw sugar factories were collected. Later, cost comparisons were made between sampling by hand and by mechanical grab, and using the three-roll sample mill and the chipper-Waring blender. For these comparison studies, current equipment and labor costs were used. Laboratory equipment, buildings, and furnishings which were common to both methods of processing the sample were neglected. These data, which are expressed as annual costs and costs per sample, are summarized in Table VI.[25] According to these figures, the

[25] "Supplemental Report - Sugar Cane Sampling Costs," A report of work done under Contract No. 12-25-010-558 with the United States Department of Agriculture, (October 22, 1959).

TABLE VI

COMPARATIVE COSTS OF SAMPLING AND PROCESSING THE SAMPLE*

Basis: 7000 Samples per Crop Year

Mechanical versus Hand Sampling

Item	Hand Sampling	Mechanical Sampling
	$/Year	
Depreciation Charges**	--	$ 90.00
Labor Needs, man-hours	2,520	1,680
Labor Costs***	$3,150.00	$2,100.00
Total Costs	$3,150.00	$2,190.00
	$/Sample	
Cost	$ 0.45	$ 0.31

Sample Preparation and Analysis

Item	Three-Roll Sample Mill	Chipper-Waring Blender
	$/Year	
Depreciation Charges****	$ 330.00	$ 128.00
Labor, man-hours	4,200	7,560
Labor Costs***	$5,250.00	$9,450.00
Total Costs	$5,580.00	$9,578.00
	$/Sample	
Cost	$ 0.80	$ 1.37

*Neglecting all costs other than those due specifically to sampling methods.

**An hydraulically-operated mechanical grab is estimated to cost $1800.

***Basis: $1.25/man-hour.

****A 12" x 12" three-roll motor-driven sample mill is estimated to cost $6600. A chipper and three Waring blender units are estimated to cost a total of $2550.

estimated annual cost of sampling by mechanical grab and processing the sample with the three-roll sample mill is about $1.11 per sample for a factory which averages about 7000 samples per year.

CHAPTER VI

SUGAR CANE QUALITY DETERMINATION FOR CANE PAYMENT

BY

SAMPLE MILL JUICE EXTRACTION

THOUGHTS ON CURRENT METHODS OF DIRECT CANE QUALITY DETERMINATION

General

Various methods of cane quality determination for cane payment in Louisiana and other sugar cane growing areas of the world have been reviewed in previous chapters. From these discussions it is evident that the primary requisite of a workable system of cane quality determination is the ability to predict accurately the value of a consignment of cane. Since the primary product from sugar cane in most cases is raw sugar, then the problem becomes specifically that of predicting the amount of raw sugar which can be recovered from a consignment of cane.

The indirect method of cane quality determination is quite well established. In this system, cane is sampled, tested, and evaluated — after it enters the carrier — by means of crusher juice samples and concurrent fiber determinations on samples of cane removed from the carrier. Indirect cane quality determination is applicable where the cane is essentially clean and trash-free.

The increasing incidence of mechanical harvesting and loading has resulted in the introduction into the mill tandem of large quantities of extraneous material including field soil. The subsequent recourse to continuous or intermittant washing of cane on the feeder table or in the carrier - with the subsequent dilution of the crusher juice samples - has made methods of indirect cane quality determination virtually inoperable.

In recognition of the problems introduced into cane sampling by mechanization of the field operations, numerous studies in many areas of the world have been directed toward evolving methods of direct cane quality determination, i.e., evaluation of cane samples which are removed before the cane enters the feeder table or the carrier. Other than Louisiana and Hawaii, these studies have been confined to the laboratory or pilot stage, and there are little data available on commercial scale applications of direct cane evaluation methods.

In Louisiana and Hawaii, the field operations are essentially 100 per cent mechanical. In Hawaii, where cane is preponderantly administration or factory owned, the emphasis in cane evaluation has been directed to factory and field control. On the other hand in Louisiana, where about 50 per cent of the cane is supplied by independent cane farmers, direct cane quality evaluation for cane payment has been quite general for the past 10 years. Here, because of the many problems associated with direct cane evaluation, extensive studies have been directed to sampling, testing, and evaluation which are applicable specifically to Louisiana conditions.

Despite the volume of research in Louisiana on the subject, no satisfactory alternative has evolved to the normal juice basis for cane quality determination. Normal juice pol – and later purity – as a criteria of cane quality were originally incorporated many years ago in the indirect system of crusher juice sampling. Initially, when cane was hand-cut and cleaned – and the varieties were significantly fewer in number – this method may have been reasonably satisfactory. The normal juice quality of the cane as determined by application of a dry milling (Brix) factor to the crusher juice Brix and a pol factor to the crusher juice pol may have given a fairly satisfactory measure of the cane quality.

Unfortunately, in adapting normal juice quality to direct cane quality determination, still another factor has been added in addition to the dry milling factor, i.e., the dilution compensation factor by means of which the sample mill juice quality is factored to that of the crusher juice. Presumably by this factor we are able to infer what the crusher juice Brix would have been if it were not diluted by wash water.

In addition to the use of the dry milling factor and the dilution compensation factor, the current normal juice method has another serious limitation. From its very inception, the system of normal juice quality determination omitted an important criterion of cane quality, i.e., the volume of extracted or extractable juice. This has resulted in the anomaly that two growers – delivering cane of the same normal juice pol – receive the same payment even though the dry fiber of one shipment may average 12 per cent and that of the other 15 per cent.

Reasoning Behind Previous Louisiana Sampling Studies

It is apparent that a reasonably accurate method of cane quality determination for cane payment in Louisiana should satisfy at least the following conditions: (1) The method should be applicable to sampling the cane before it enters the carrier; (2) the quantity as well as the quality of the juice should enter into the determination; and (3) a minimum of factors should enter into the determination.

The line of reasoning in previous studies at the Audubon Sugar Factory has followed that of the research in direct cane quality determination in other areas of the world. The Audubon Sugar Factory studies and the concurrent studies elsewhere have all started with the analysis of the cane *per se*, i.e., pol, fiber, and Brix per cent cane. Thus in order to predict the available sugar in the cane, it is first necessary to infer the milling response of the cane consignment – or the extraction – from the fiber content of the sample. The crux of this method of quality prediction is thus the fiber in the cane. It seems reasonable to ask: (1) How good a criterion of extraction _is_ fiber? (2) How accurate are the routine methods of fiber determination? and (3) How extensive are the laboratory facilities which are required and what is the scope of control which is necessary if fiber is included in the routine sampling procedure?

Fiber as a Criterion of Extraction: Assuming that the dry fiber in a sample of cane is properly determined, does the fiber itself permit one to accurately predict the milling response of the cane consignment? Unfortunately, there are limited literature data available to show that with a given set of milling conditions, and knowing the dry fiber in the cane, it is possible to predict with reasonable accuracy the juice or the pol extracted under conditions of varying variety, different pol content of the cane and varying amounts of trash.

Current studies at the United States Department of Agriculture Experiment Station at Houma, Louisiana, raise the question as to whether dry fiber _per se_ is a true criterion of _juice extraction_. In these studies, which have not been published as yet, cane stalks were cut into the top one-third and the bottom two-thirds sections. The tops and bottoms were separately milled in a three-roll sample mill and the juice extraction and fiber per cent cane determined. The test data showed consistently _lower_ fiber in the top one-third of the stalks as well as lower juice extraction than in the bottom sections of the stalk.[1]

The cold water extraction process, a method of direct cane quality determination, is specifically geared to the determination of dry fiber – from which the commercial mill extraction is subsequently predicted. Interestingly enough, in several adaptations of the process, the calculations of pol in the cane involve the assumption that dry fiber is not the only residue removed in the conventional milling operation. It is hypothesized that both dry fiber and Brix-free water pass through the milling train unaffected by the compression effect of milling. Brix-free water is defined as water adsorbed on the cane fiber and/or held by physico-chemical bonds so that it is unavailable for solution. As such it is not removed by the compression effect of the mills, for the bonds are broken only by the application of heat as in a bagasse oven. The Brix-free water may be of the order of 20 to 30 per cent of the dry weight of the fiber.[2,3] Thus in determining the pol in the extract from the extractor, the dry fiber is corrected for the presence of Brix-free

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[1]Discussions with Dr. L. P. Hebert, Research Agronomist at the United States Department of Agriculture, Houma, Louisiana, Experiment Station.

[2]S. R. Harris, P. A. Hanks et alia, "Direct Analysis of Cane Using a Wet Disintegrator," Proceedings of the Tenth Congress of the International Society of Sugar Cane Technologists, (1959), p. 189.

[3]K. Douwes Dekker, "A Survey of the Work Done in S.A. on the Direct Analysis of Cane Consignments," Sugar Milling Research Institute, Quarterly Bulletin No. 7, (August, 1958), p. 25.

water. In the actual calculations, the extract is determined to be the difference between the sum of the cane plus added water less the product of dry fiber times a factor. The factor, which may be the order of 1.20 to 1.30, corrects the weight of dry fiber to the weight of dry fiber plus Brix-free water.

Hence in the routine determinations for pol in a cane sample, an allowance is made for Brix-free water, a substance which is apparently unaffected by the compression effect of the mills. However, in subsequent predictions of the commercially extractable pol in the sample, dry fiber is assumed to be the only variable affecting the milling response of the sample.

The Accuracy of Routine Methods For Fiber Determination: In informal studies at the Audubon Sugar Factory, considerable variation was observed in the results of replicate fiber determinations on the same sample of bagasse. The problem was traced to the coarse nature of the bagasse from the three-roll sample mill. Even duplicate milling of the cane sample produced a bagasse of varying particle size. Generally, the reproducibility of the fiber determination was significantly improved by extending the drying time -- thereby attaining a constancy in the moisture determination.

Along the same line, rather poor reproducibility was obtained with the determination of pol in bagasse from the sample mill in the same studies. Again the problem seemed to be centered on the lack of uniformity in the size of the particles of bagasse. Bliss, in Cuban studies, notes a definite relationship between size of the bagasse particles and the pol content of the particles. Very large bagasse particles from the mill tandem showed twice the pol content determined for the smallest particles.[4] While Bliss's presentation was an argument for more effective cane preparation and milling to achieve a high degree of bagasse disintegration, the results also point up the problem of analyzing bagasse of varying particle size. Such a lack of particle uniformity results from only one or two passes through the three-roll sample mill.

To improve the precision of inspections of the bagasse from the sample mill – both fiber and pol – a laboratory scale shredder is probably a necessary adjunct to the three-roll sample mill in order to provide a uniform and finely subdivided bagasse particle size for subsequent inspections.

Theoretically, it would appear that the cold water extraction process <u>should</u> be superior to the three-roll sample mill for analyzing the constitutents of the cane itself, i.e., Brix, fiber, and pol per cent cane. The pulping actions of the blades would provide a final residue well disintegrated and uniformly extracted.

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[4]L. R. Bliss, "El Analysis Provechoso del Bagazo," Memoria de la XXXI Conferencia Anual de la Asociacion de Tecnicos Azucareros de Cuba, (1957), pp. 225-234.

Requirements for Running Routine Fiber Determinations: Anderson notes that in Queensland, about 150 fiber determinations were run weekly in a factory test series on the Juice Scales-Individual Fiber CCS System for determining cane quality. In this case, at least one fiber determination was made for each grower weekly.[5]

Paul in his studies at the Audubon Sugar Factory assumed about 700 samples per week in developing the comparative costs of sampling by hand and by mechanical grab, and processing the sample in the three-roll sample mill and the chipper-Waring blender.[6]

In discussing the Reunion SE method of cane quality determination, Hugot notes that between 300 and 1,000 fiber determinations were made per factory during the 1954 crop.[7]

It would appear that appreciable laboratory equipment, personnel, and supervision are necessary in order to perform routine fiber determinations as part of the cane quality determination. In recognition of this, rather extensive studies in South Africa were

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[5]G. A. Anderson, "The Juice Scales-Individual Fiber System for the Determination of Cane Quality," Proceedings of the Tenth Congress of the International Society of Sugar Cane Technologists, (1959), p. 185.

[6]"Supplemental Report – Sugar Cane Sampling Costs," A report of work done under Contract No. 125-25-010-558 with the United States Department of Agriculture, (October 22, 1958).

[7]E. Hugot, "Cane Payment on a Quality Basis, An Extractable Sugar Formula in Reunion," The International Sugar Journal, LVII (1959), 187-190.

directed toward simplifying the procedure for making routine fiber determinations. However, none of the "streamlined" methods gave the desired accuracy.[8]

Miscellaneous Comments on the Cold Water Extraction Process: As noted above, the use of fiber as a criterion of cane quality raises questions as to the accuracy of the subsequent extraction predictions, the precision of the routine methods for fiber determination, and the rather extensive personnel, laboratory equipment, and supervision which are necessary to incorporate fiber into the cane payment system.

With regard to the cold water extraction process itself, it appears that special considerations may have to be made as to laboratory equipment and the methods of calculating cane quality from the extract and residue inspections. In order to accomodate the low extract concentration, the pycnometer is used in Australia to determine the Brix or soluble solids rather than the hydrometer spindle. In Hawaii, the precision type refractometer is used.

In South Africa and Australia, the method of calculating the pol in the extract from the extractor is refined to include a correction

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[8]C. van der Pol and C. M. Young, "Determination of Certain Qualities of Individual Cane Consignments," Sugar Milling Research Institute, Quarterly Bulletin No. 5 (January, 1958), pp. 9-13.

for Brix-free water.[9,10] As mentioned previously, the weight of the extract is assumed to be that of the cane charge plus water less the product of dry fiber times a factor to correct for Brix-free water in the residue. However, in Hawaii, the procedure is the more conventional one of merely deducting the weight of the dry fiber from that of cane plus water.[11]

AN ALTERNATIVE METHOD OF DIRECT CANE QUALITY DETERMINATION BY SAMPLE MILL JUICE EXTRACTION

The preceding discussion is not meant to be an indictment of the concept of fiber as a criterion of cane quality nor of the cold water extraction process as a means of defining cane quality. It is suggested, however, that the objections cited above are sufficiently valid to warrant serious consideration of alternative methods of direct cane quality determination which incorporate neither fiber nor the use of the cold water extraction process.

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[9] Harris, Hanks et alia, Ibid., p. 189.

[10] Douwes Dekker, Ibid., p. 25.

[11] John H. Payne and Henry J. Mahon, "The Pol Ratio Method for Evaluating Cane Quality," Proceedings of the Ninth Congress of the International Society of Sugar Cane Technologists, Vol. II, (1956), p. 441.

Such an alternative is suggested by the use of the three-roll sample mill in lieu of the cold water extraction process in the Audubon Sugar Factory studies. In these studies, the sample mill was used to prepare cane samples for subsequent Brix, fiber, and pol determinations. It is reasoned that the sample mill extraction itself - rather than the fiber content - is a sufficient criterion of the commercial scale milling response of the sample. In such a case, fiber determinations are no longer necessary. Obviously, the question to be answered is whether the extraction of a well designed sample processing or milling device bears a relatively reproducible relationship to that of a commercial scale milling tandem. For many years, a hydraulically loaded three-roll sample mill has been used at the USDA Houma, Louisiana, Experiment Station in agronomic research. In typical varietal milling studies, factors are determined which relate the results from a single pass through the mill with those from multiple milling of the same variety in the mill under essentially commercial conditions of maceration and mill pressure. The factors have exhibited a high degree of reproducibility - so much so that it has been suggested that a comparable method of cane evaluation might be evolved for cane payment purposes. However, no specific methods of commercial scale application have been suggested.[12]

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[12]George Arceneaux, "Standards of Cane Quality in Relation to Agronomic Research and Commercial Evaluation of Mill Cane," Paper delivered before the American Society of Sugar Cane Technologists, February, 1960.

With these thoughts in mind, screening studies were made at the Audubon Sugar Factory during the 1960 crop in which the extraction of different sample processing or milling devices was compared to that of the factory mill tandem. In these studies, the cane feed and the extracted juice weights of the sample were determined, and from the juice inspections, the pol and brix extraction per cent cane were calculated. These results were compared with those from the big mill. The big mill was operated under constant conditions of maceration, mill speed, setting and pressure. The sample processing devices which were studied included (1) single milling through the three-roll Farrel sample mill, (2) preparing the cane sample in a small shredder followed by single milling in the sample mill, and (3) extraction of chipped cane in an extruder-type cotton seed oil screw press.

In these sampling studies, considerable difficulty was experienced in maintaining uniform feed of the shredded cane through the three-roll sample mill, and the juice extraction varied widely – even in tests on cane from the same lot. However, the results from milling of the whole cane in the three-roll mill and of processing the cane through the screw press were quite encouraging.

Concurrent with the 1960 studies at the Audubon Sugar Factory, a plant scale application of the sample mill juice extraction system was tried at the Helvetia Cooperative raw sugar mill through the cooperation of Mr. Jules Dornier, Jr., manager. In these plant scale studies, the routine normal juice determinations were made for cane payment which included inspections of the juice from the three-roll sample mill. However, in addition, all juice was weighed, from which the pol and Brix extraction per cent cane were determined for each sample. These data were weighted to reflect the average sample mill pol and Brix extraction per cent cane for all shipments during the weekly run. From the corresponding big mill data for the same period, pol and Brix extraction factors were calculated. These factors related the extraction of the sample mill with that of the big mill. These factors showed quite good reproducibility from week to week.

Based on the results of the sample mill juice extraction studies on a pilot scale at the Audubon Sugar Factory, and on a plant scale at Helvetia Cooperative, plans were made for a comprehensive series of tests during the 1961 crop.

CHAPTER VII

EXPERIMENTAL PROCEDURE, EQUIPMENT, AND HANDLING OF DATA

SUMMARY

Because the experimental work during the 1961 crop covered a rather wide range of investigation, the scope of the work, the equipment, and the procedure are summarized in this section in order to provide an overall picture of the project. The material in this summary are covered in greater detail in subsequent sections.

As noted in the preceding chapter, the normal juice method of cane quality determination as used in Louisiana has many shortcomings including its use of a multiplicity of factors, its failure to interpret cane quality in terms of recoverable sugar and its failure to incorporate into the cane quality the quantity of juice in the cane. In other cane growing areas, the most recent developments in direct cane quality determination, i.e., the evaluation of cane before it enters the carrier, base the predicted recoverable sugar on the inspections of the cane itself - that is, the apparent sucrose - or pol, the Brix, and the fiber per cent cane. With this approach, the laboratory equipment, personnel, and supervision which are required for routine fiber determinations are appreciable. In addition, there is the question as to how reliable is a milling extraction which is predicted from the fiber content of the cane sample.

An alternative possibility to be considered is the use of a prototype sample milling or processing device to predict the juice extraction or milling response of a sample of cane. Such a device would have to be reproducible in performance and show a reasonably consistent relationship with the extraction of the factory mill. By this method, a direct means would be available for predicting factory extraction compared to the inferential method as required with fiber. This possibility forms the basis for the subsequent studies at the Audubon Sugar Factory.

In <u>any</u> of the methods of cane quality determination which involve a prediction of the recoverable sugar in the sample, <u>both</u> mill extraction and boiling house retention must be determined. While these studies have been confined to the evaluation of the milling extraction of the sample, it is still necessary to predict the recovery of the extracted sucrose in the boiling house by means of one of the conventional retention formulas — in conjunction with an assumed boiling house efficiency. The phase of cane quality determination dealing with the boiling house response is itself a field which is vitally in need of investigation. For these studies, an assumed boiling house retention was applied to the extraction data.

During the 1961 crop, the study program covered the following sample processing devices for predicting the extraction of a consignment of cane:

1. The Three-Roll Sample Mill
   a. Once Through
   b. Twice Through
2. The Screw Press
3. A Small box-type hydraulic press similar in construction to the laboratory cage press.

In these studies, samples for each of the processing devices were removed from the opened bundle of cane on the feeder table. Having removed the samples, the remainder of the cane was processed on the factory milling tandem. Juice and bagasse from the samples and the factory tandem were weighed and inspected and the appropriate calculations were made which would permit comparison of the sample milling or processing results with those of the factory mill.

By regression analyses, the Brix and pol extraction of the sample processing devices were compared with the factory extraction in terms of a single variable linear correlation of the form $y = a + bx$. The degree of correlation was statistically tested by the correlation coefficient r, the standard deviation of the estimate $s(\hat{y})$, the coefficient of variance, and the 95 per cent confidence limits of one sample.

In addition to the correlations relating the sample mill extraction to that of the factory, correlations were also developed which related the Brix, pol, and fiber per cent cane of the sample with similar inspections of the whole cane consignment as determined from the factory results. This phase of the studies permitted a comparison of these data with similar data from previous studies.

Because of the emphasis in concurrent studies on the use of fiber as a means of predicting mill extraction, correlations were also developed relating the fiber content of the sample to the factory juice extraction of the whole consignment. The precision of these correlations were compared statistically with that of correlations relating the <u>sample mill juice extraction</u> to the factory juice extraction.

From the sample and factory data, the factors used in the normal juice method of cane quality determination were studied. The daily and average dilution compensation factors (Factory Crusher Juice Brix/Sample Mill Juice Brix) and dry milling factors (Factory Normal Juice Brix/Factory Crusher Juice Brix) were determined. From these data, 95 per cent confidence limits for one dilution compensation factor test and one dry milling factor test were determined.

Finally, the sample mill extraction method of cane quality determination was applied to a cane payment system. In this phase of the studies, average Brix and pol extraction factors were calculated. These factors related the sample mill extraction to that of the factory. The extraction factors and a standard retention and boiling house efficiency were applied to the daily sample mill data in order to determine a predicted yield of 96° sugar. The predicted cost of cane was subsequently calculated using the 1961 season's average price of 96° raw sugar and a standard distribution of returns for sugar between the grower and processor.

In addition, the cost of cane was predicted by means of the conventional normal juice method as applied to the sample mill data.

The cane cost was also calculated using the cane quality as determined from the sample mill Brix, pol, and fiber per cent cane and the correlations relating these inspections to the corresponding factory data. A standard factory extraction – and retention and boiling house efficiency – were applied to the cane quality as determined from the correlations in order to determine a predicted yield. From the yield, the cost of cane was determined assuming the standard distribution of returns and price of sugar as with the sample mill juice extraction method.

EQUIPMENT

Sample Milling or Processing Devices

Three-Roll Sample Mill – The three-roll sample mill (Illustration 2) which was used in these studies was designed by the staff of the Chemical Engineering Department and the Audubon Sugar Factory, and constructed and presented to the Audubon Sugar Factory by the

THREE-ROLL SAMPLE MILL

Illustration 2

Farrel-Birmingham Company of Ansonia, Connecticut. The mill weighs 14,125 pounds and measures approximately six by eight feet. All metal sections of the mill are annealed and stress-relieved. The mill is powered by a 220-440 volt, 15 HP motor with a four to one speed variation which gives an effective mill speed of about eight to forty feet per minute. A 4-1/2 inch floating shaft connects the reducer to the actual mill. This shaft drives the cane grinding unit which consists of three twelve inch by twelve inch rolls. The rolls are grooved to three-eighth inch with a pitch angle of 50^{o}.

The mill is equipped with a Blackhawk hydraulic system which consists of a pump and oil reservoir mounted on the machine base. This system is capable of delivering a maximum hydraulic pressure of 2000 psig which is equivalent to forty one tons per foot of top roll. The hydraulic system includes two Edwards accumulators with piping, gauges, and roll float indicators. The mill employs a central force-feed lubrication system which distributes oil to six points on the mill.

The cane feed chute is twelve inches wide by eight inches deep, and is mounted at an angle to facilitate feeding. The bagasse chute, which is wider than the rolls, is inclined at an angle to provide gravity discharge of the bagasse.

Galvanized iron trays approximately five feet long by twelve inches wide by eight inches deep are provided to facilitate feeding cane or bagasse to the mill. The trays are so constructed that the cane or bagasse can be placed in the trays and the trays inserted in the cane feed chute. When the trays are tilted the feed enters the mill by gravity.

Screw Press - The screw press (Illustration 3) which was used in these studies is of the basic design for the extraction of oil from cotton seed. The press with some modifications for sugar cane extraction was loaned to the Audubon Sugar Factory by the French Oil Machinery Company of Piqua, Ohio, the manufacturer.

In previous studies, the press showed better pol extraction on cane samples than was observed with the factory tandem on the whole cane shipment. As an indication of extraction severity, it was noted that moisture in bagasse averaged 37 to 42 per cent on bagasse, while the factory tandem ranged from 46 to 48 per cent. The manufacturer's specifications on the Machine No. 15378 are:

3-section frame, rectangular downspout.

SCREW PRESS

Illustration 3

3-section solid cage, heavy duty, F2 screen bars, spaced .039 in., .020 inc., .010 in.

Auxiliary drainage cage, spaced .040 in.

Main shaft assembly for sugar cane, light-weight solid shaft, all hard coated worms and collars.

Stationary cone center discharge, motor driven.

50 HP, 1800 rpm, U.S. motor with starter, 3/60/220.

80-20 gear arrangement

Box Press - The box press (Illustration 4) used in these sampling studies was designed especially for this service and was fabricated by the University Engineering Experiment Station. The unit as completed closely resembles the laboratory type cage press except that it is much larger, and instead of the cylindrical cage, a section of standard eight inch pipe was used.

The frame consists of two vertical eight inch I beams and two top and two bottom horizontal stringers of three inch by ten inch angles. A three-fourths inch base plate is welded to the top of the bottom stringers to support the hydraulic jack, and another base plate of the same dimensions is welded to the bottom of the top stringers to hold the fixed piston.

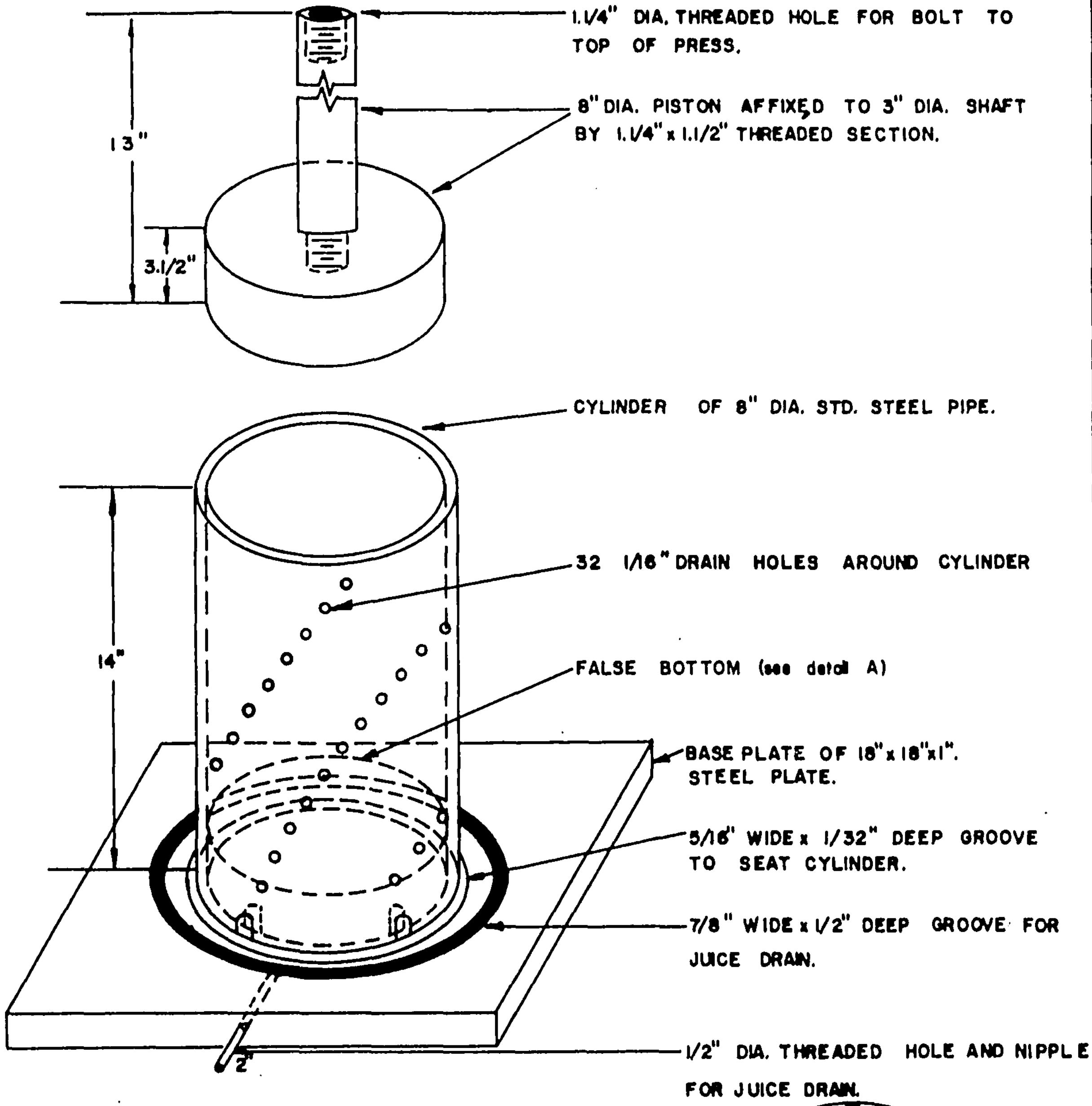
BOX PRESS

Illustration 4

The manually operated hydraulic jack is rated at twenty tons capacity. The press piston – a 3-1/2 inch thick section of eight inch round is threaded to a section of three inch round of sufficient length to permit a thirteen inch stroke of the cylinder. The cylinder assembly (Illustration 5) which consists of a cylinder, base plate, and false bottom, is affixed to the jack by means of a collar and set screw on the base plate which engages the jack piston.

The cylinder, which was fabricated from a section of eight inch standard steel pipe, is fourteen inches high. To facilitate drainage of the expressed juice, 1/16th inch holes were drilled in the wall of the cylinder. The 3/4 inch base plate is grooved to receive the cylinder, and a 7/8 inch gutter has been machined into the base plate near its perifery to receive the juice. Drainage of the juice from the gutter is by means of a small spout which has been threaded into the side of the base plate – opening into the gutter.

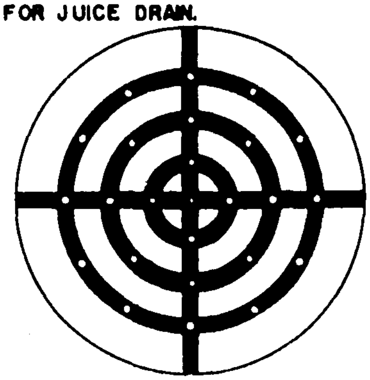
Located inside the cylinder and resting on the base plate is a removable false bottom. The bottom is provided with holes and circumferential and radial grooving to permit drainage of the juice from the cylinder.



DETAIL A

FALSE BOTTOM.

1/2" THICK WITH 1/16" DIA. HOLES AND DRAIN CHANNES.



BOX PRESS CYLINDER ASSEMBLY AND PISTON.

ILLUSTRATION NO. 5

The pump hydraulic system is piped to a pressure gauge. The maximum pressure of 10,000 psig corresponds to a working pressure in the eight inch cylinder of about 800 psig.

Factory Milling Equipment

Cane is handled by a four ton American steel guy derrick. The feeder table is of the conventional type steel construction approximately eighteen feet by twenty feet equipped with feeder chains which are driven by a speed reducer and motor with a rheostat speed control. The feeder table discharges into a four foot steel slat cane carrier. The carrier too is actuated by a rheostat controlled electric motor.

The cane is prepared by means of two sets of knives. The first set, which is located just off the feeder table, consists of twenty four knives driven at 600 rpm by a 75 HP A.C. motor through a V-belt drive and set at 2-1/2 inches from the slats. The second set, at the head shaft of the main conveyor, consists of 24 knives driven at 600 rpm by a 40 HP A.C. motor through a V-belt drive, and is set at 3/4 inches from the slats.

The Squier milling tandem is made up of a twenty by twenty-four inch Fulton type two-roll crusher, followed by three triangular stress 18-1/2 by 24 inch three-roll mills. The individual units are driven by independent direct current motors through double reduction Falk gearing. The crusher is driven by a 50 HP motor, and each of the mills is driven by a 100 HP motor. The roll speed of the three-mills and crusher may be uniformly varied in the range of twenty through eighty feet per minute by varying the output voltage of the Ward-Leonard system motor-generator set. The roll speed of the individual mills may be adjusted by varying the field current on the motors. Roll pressures are maintained by Edwards accumulators at the ends of the top roll of each mill.

A complete material balance around the mill is provided by cane, bagasse, maceration, and juice measuring or weighing equipment. The cane is weighed at the derrick by means of a four ton Howe derrick scale. The juice weight is provided by the pneumatically operated Foxboro juice weighing system. Bagasse is baled and then weighed on Buffalo Scale Company equipment.

In order to run the dry milling tests – which require the determination of the Brix of undiluted juice – no maceration water was used on the mills. However, maceration water metering equipment is available.

Miscellaneous Equipment

Mechanical Grab: The mechanical cane sampling grab is constructed of steel piping and cable. Operation is hydraulic through an electric motor which creates an operating pressure of about 1900 psig. Three hydraulic cylinders, which are manually actuated by means of levers, move the grab in a horizontal plane, lift the grab arm, and close the grab. By means of cable, the grab unit can be manually positioned over the cane on the table. The boom is 18 feet in length, while the grab unit is 1-1/2 feet in length with a holding diameter which may be varied from about one to 2-1/2 feet. The operating capacity of the grab is approximately 30 to 150 pounds of cane.

Ensilage Cutter: The Model 340 Letz Fodder and Hay Chopper, which is manufactured by the Letz Manufacturing Company of Crown Point, Indiana, consists of an electric motor driven steel slat conveyor, "finger feed" comprising a drum with four rows of staggered steel fingers, and a cutterhead. The conveyor belt carries the cane - or any fibrous material - through the finger feed into the cutter head where the feed is cut into small sections.

Y-Type Blender: The Y-type blender consists of two cylinders welded into the shape of a V and combining into a single vertical cylinder at the junction. The unit, which has an operating capacity of about 40 gallons, is powered by a 1/4 HP electric motor. It is driven through a gear reducer at a speed of about 10 rpm.

Miscellaneous equipment for preparing the samples for laboratory testing were 500 pound maximum capacity platform scales;

pallets, which were constructed of half-sections of 55 gallon drums for transporting the cane samples in the area; 10, 20, and 55 gallon containers for juice and bagasse; and #10 cans for the laboratory samples. A laboratory pan balance was used for the smaller samples which were required for the box press.

PROCEDURE

Generally four bundles of cane (each weighing two to three tons) were processed in each run. Prior to the test, the bundles were selected from those in the cane yard to represent the same variety and quality of cane with respect to freshness and trash or degree of burning. As each bundle of cane was placed on the feeder table and opened, a mechanical grab sample of approximately 110 pounds was removed from the bundle and placed on the platform. Each grab sample was subdivided into four sub-samples. This step was performed with care to minimize the loosening or loss of trash in the sample. The sub-samples were labeled:

1. Trash Determination
2. Three-Roll Sample Mill – Single Milling
3. Three-Roll Sample Mill – Double Milling
4. Screw Press and Box Press

The remaining bundles were sub-sampled in the same manner, and the sub-samples were composited and tied.

Trash

The sub-sample labeled Trash Determination was weighed, hand cleaned, and reweighed from which data the per cent trash was determined. In the hand cleaning, all leaves, extraneous material, and tops above the last full-formed joint were removed.

Three-Roll Sample Mill

In the three-roll sample mill processing, the cane samples for the single and for the double milling were weighed and then placed in the galvanized feed troughs. The cane was uniformly spread in the troughs to a depth of about three layers of cane. The feed troughs were centered in the mill feed chute and tilted so that the cane entered the mill by gravity feed. In the double milling, the bagasse was milled again – the feed being evenly spread in the feed troughs. The weights of the juice and bagasse were recorded. The bagasse from the double milling study was placed in the Y-type tumbler and mixed for ten minutes after which a one-gallon sample was removed. The bagasse sample and the one-gallon juice samples from the single and the double milling were set aside for transfer to the laboratory. No bagasse samples were collected from the single milling due to the coarse nature of the residue.

Uniform milling conditions were maintained in all runs at a mill roll speed of about 8.5 feet per minute and a hydraulic pressure of 1300 psig or about 27 tons on the top roll.

In all runs, feed to the sample mill was such that the upper roll "floated" as indicated by the roll movement indicators. In this manner, maintenance of the indicated load on the cane mat was assured.

Screw Press and Box Press

The single sub-sample for the screw press and the box press was prepared in the ensilage cutter during which time a sample of about 10 pounds was removed from the shredded cane for the box press feed. The remaining prepared cane was weighed and charged to the screw press. The juice and bagasse products were weighed, and the bagasse was placed in the Y-type blender and mixed for ten minutes after which a one-gallon sample of bagasse was removed from the blender. The bagasse sample and a sample of the juice were set aside for transfer to the laboratory.

Early in the study, it became evident that a residue of bagasse and juice was remaining in the press from the preceding runs, and this material was souring. To minimize contamination between runs, the practice was adopted of purging the unit with several stalks of cane prior to each run. In addition, it was found to be necessary to feed the cane to the screw press with care to minimize the possibility of choking the unit.

The feed for the box press was weighed and placed in the eight inch diameter cylinder. By means of the jack, the cylinder was raised so that the stationary piston exerted pressure on the cane mat.

Pressure was applied on the hydraulic system to the limit of 10,000 psig as indicated by the gauge. This pressure corresponded to approximately 800 psig on the bagasse mat. Pressure was maintained on the mat for five minutes after which it was released.

Juice and bagasse were weighed and the bagasse was thoroughly mixed by hand after which a one-gallon sample was removed. The bagasse and a sample of juice were set aside for transfer to the laboratory.

Factory Mill Tandem

At the beginning of each run the carrier, mills, bagasse conveyor, and the mixed juice transfer lines from the mill tanks to the weighing tanks were empty. Initial measurements were made of the juice in the mill juice tanks and the Foxboro weighing tanks as well as the bagasse in the baler.

As each bundle of cane was placed on the feeder table, its weight was recorded. The run commenced when the knifed cane entered the crusher. Sampling commenced thirty seconds after the bagasse was first discharged from the last mill. Samples of the crusher, mixed, and last mill juice and bagasse from the third mill were collected. Automatic crusher and mixed juice sampling devices were utilized. The run ended when the last of the bagasse mat was discharged from the third mill. During the run, the baled bagasse was weighed over the bagasse scales.

After the run, measurements were made of the juice in the mill tanks and the Foxboro tanks as well as the bagasse in the baler. The weight of the juice was corrected for any change in the inventory of mixed juice in the mill and Foxboro tanks. In a like manner, the weight of the bagasse was corrected for any change in the inventory of bagasse in the baler. Juice and bagasse weights were corrected for the weight of samples removed. The weight of cane milled was assumed to be the sum of the weights of juice plus bagasse unless there was exceptional disagreement between this value and that of the cane scale.

The operating conditions on the factory mill tandem during the runs averaged: mill roll speed about 40 fpm., hydraulic pressure in tons per linear foot – crusher 23, 1st mill 26, 2nd mill 33, 3rd mill 36.

Laboratory Analyses

Juice Brix was determined by means of the hydrometer while pol was by Horne's dry lead. Moisture in bagasse was determined by drying the bagasse in the Dietert Moisture Teller for two 15 minute cycles. Pol by digestion and fiber by difference followed the procedure outlined in Section 711 of Cane Sugar Handbook (Eighth Edition).

Data

Since the first week of operation was devoted to "ironing out the bugs" in the procedure, tabular material from this period was discarded. Data for the remainder of the crop are tabulated in the Appendix by run. These data include the routine juice and bagasse inspections for the sample processing devices and the factory mill tandem as well as the preliminary calculations covering cane quality, i.e., Brix, pol, and fiber per cent cane, and extraction data. Typical calculations covering this phase of the study are also shown in the Appendix.

HANDLING OF DATA

Summary

Calculations were developed along the following major areas of investigation:

1. Correlation and comparison of the sample with the factory data.
2. Application of the sample data to a cane payment system and calculation of the cost of cane by different methods of cane payment.

Correlation and Comparison of the Sample with the Factory Mill Data

Pol and Brix Extraction: Since these studies were directed toward evolving a means of predicting the factory mill extraction from a sample of cane, of primary interest were correlations relating the sample to the factory mill extraction and the accuracy of the correlations. By means of regression analyses, linear correlations were developed between the sample mill and the factory mill pol extraction for each of the sample processing devices.[1, 2] These correlations took the form:

$$\hat{y} = a + bx$$

where: $\hat{y}$ is the predicted factory mill extraction, lbs. pol extracted per ton of cane.[3]

x is the sample mill pol extraction, pol extracted per cent cane.

a and b are the intercept and regression coefficient respectively.

The degree of correlation and the accuracy of each device were determined in terms of the following factors:

The correlation coefficient r.

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[1]In the 1960 screening studies, various types of correlations were tried including multiple dependent variable relationships as factory pol extracted per cent cane versus the sample pol and fiber per cent cane. In addition, relationships were tested between the factory operation and the sample mill performance as a single variable raised to a power. None of these relationships showed any improvement over the simple linear single variable correlation.

[2]Typical statistical calculations are shown in the Appendix.

[3]Pol extraction was expressed in lbs. pol per ton of cane rather than pol per cent cane since the subsequent cane payment calculations required the predicted yield in pounds of 96° sugar per ton of cane.

The goodness of the correlation (r^2) -- or the fraction of the sum of the squares which is accounted for by the correlation.

The standard deviation of the estimate s ($\hat{y}$).

The coefficient of variation.

The 95 per cent confidence limits of one test at the average extraction of the runs.

Although the pol extraction was of primary interest, the Brix extraction is also necessary in order to predict the retention of sugar from the extracted juice -- the retention being a function of the purity of the extracted juice. For this reason, correlations for Brix extraction were developed similar to those for pol, and the accuracy of the correlations was similarly tested.

Three primary factors enter into the calculation of the pol or Brix extracted. These factors are the juice extracted and the inspections of the juice, i.e., pol extracted = juice extracted x pol per cent juice <u>or</u> Brix extracted = juice extracted x Brix per cent juice. The question arises: How reproducible is the relationship between factory and the sample mill for each of these factors? In order to answer this question, the following relations were calculated for each sampling device:

$$\text{Juice Extraction Factor} = \frac{\text{Factory Mixed Juice Extraction, \% Cane}}{\text{Sample Mill Juice Extraction \% Cane}}$$

$$\text{Pol \% Juice Factor} = \frac{\text{Pol \% Factory Mixed Juice}}{\text{Pol \% Sample Mill Juice}}$$

$$\text{Brix \% Juice Factor} = \frac{\text{Brix \% Factory Mixed Juice}}{\text{Brix \% Sample Mill Juice}}$$

The reproducibility of these factors as determined for each run was tested in terms of the standard deviation from the mean.

Sample Juice Extraction or Fiber Content as a Measure of Factory Juice Extraction: In the previous chapter, arguments were advanced against the use of the fiber content of a sample for predicting factory mill extraction. From these arguments, the hypothesis was developed that the extraction of a well designed sample mill should provide the best means of predicting that of the factory. To test this contention, linear correlations were developed in these studies between the factory juice extraction and the sample mill juice extraction as follows:

$$\hat{y} = a + bx$$

where: $\hat{y}$ is the predicted factory mill juice extraction per cent cane.

x is the sample mill juice extraction per cent cane.

a and b are the intercept and the regression coefficient respectively.

A similar correlation was derived in which x was the fiber per cent cane as determined from the sample mill data. The relative accuracy of the two predictions was tested by means of:

The correlation coefficient r.

The goodness of correlation coefficient r^2.

The standard deviation of the estimate s $(\hat{y})$.

The coefficient of variation.

<u>Pol, Fiber, and Brix Per Cent Cane</u>: In the chapter covering the cane sampling investigations at the Audubon Sugar Factory, it was evident that considerable study had been directed towards the use of the cane quality itself, i.e., pol, fiber, and Brix per cent cane, as a measure of the value of the cane — either directly or as a means of predicting the recoverable sugar in the cane. Correlations were shown relating the factory pol and fiber per cent cane with the corresponding sample inspections. Since complete cane inspections were developed from the sample mill data in the current studies, similar correlations have been developed in the following manner:

$$\hat{y} = a + bx$$

where: $\hat{y}$ is the predicted pol <u>or</u> fiber per cent cane - factory.

x is the pol <u>or</u> fiber per cent cane - sample.

a and b are the intercept and regression co-efficient respectively.

The accuracy of these predictions was tested in the same manner as explained previously.

Cost of Cane by Sample Mill Extraction

Having determined the relative accuracy of the extraction predictions by means of the various sample processing devices, the next problem becomes that of considering a cane payment system based on cane quality as predicted by sample mill extraction.

The cane payment system considered in these studies is based on the proposition that cane of equal quality should receive the same payment regardless of the factory to which it is delivered. In this manner, the grower is not penalized for inefficient factory operation, and the factory whose efficiency is above that of a certain standard receives the benefits accruing from its improvements. In summary form, the determination of cane payment by sample mill extraction incorporated the following steps:

1. Correction of the factory extraction to a standard extraction.
2. Determination of pol and Brix extraction factors

which relate the average standard factory extraction to that of the sample mill for a given period of time — say a run.

3. Application of the extraction factors to the sample mill extraction for each grower's delivery in order to determine a predicted extraction for the delivery.
4. Application of a theoretical retention formula and a standard boiling house efficiency to the predicted extraction in order to determine a predicted yield of 96° sugar.
5. Calculation of the value of the shipment based on its predicted 96° sugar content.
6. Determination of that portion of the sugar value of the shipment which accrues to the grower. This step assumes a standard split in returns for sugar between the factory and the growers delivering to the factory.

Standard Factory Extraction: There are various methods by which the factory control data covering a given period of time can be adjusted to reflect a standard extraction. Such methods come to mind as pol extraction per cent pol in cane — or reduced pol extraction assuming a standard fiber content of the cane. For purposes of this study a very simple method was adopted in which the standard extraction was determined from an assumed standard level of the pol/fiber and Brix/fiber in bagasse.[4] Then:

$$\text{Pol Extracted \% Cane; Standard Factory} = \text{Pol \% Cane} - \left[\frac{\text{Pol}}{\text{Fiber}}\right] \text{Bagasse} \times \text{Fiber \% Cane}$$

$$\text{Brix Extracted \% Cane; Standard} = \text{Brix \% Cane} - \left[\frac{\text{Brix}}{\text{Fiber}}\right] \text{Bagasse} \times \text{Fiber \% Cane}$$

The Brix in bagasse was that as determined from the pol content of the bagasse and the purity of the last mill juice.

In a system such as this, probably <u>state average</u> factory extraction as determined from the state average bagasse inspections would be the standard -- such data to be a five-year average. Unfortunately, the figures of Brix/fiber in bagasse were not available -- nor were the last mill juice inspections. For this reason, it was necessary to use the milling data of a group of selected mills, and from these data the sucrose/fiber and Brix/fiber in bagasse were determined for the concurrent 1961 crop. The respective figures were 0.7120 and 0.9766.

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[4] Probably the arguments against dry fiber as a basis for predicting the extraction response of a cane <u>sample</u> are also valid when using the ratio of pol and Brix to fiber in bagasse as a standard of <u>factory</u> extraction. It may be that the factor desired is the ratio of Brix or sucrose to dry fiber plus Brix-free water. Other methods of establishing a standard factory extraction are undoubtedly available and to be preferred in a final application of this system of cane quality determination.

Pol and Brix Extraction Factors: Factors were determined which related the sample mill to the standard factory extraction for each run as follows:

$$\text{Pol Extraction} = \frac{\text{Pol Extracted \% Cane, Standard Factory}}{\text{Pol Extracted \% Cane, Sample Mill}}$$

$$\text{Brix Extraction} = \frac{\text{Brix Extracted \% Cane, Standard Factory}}{\text{Brix Extracted \% Cane, Sample Mill}}$$

These factors were averaged for the crop. In commercial operation, the extraction factors would probably cover the period of one run.

Predicted Yield: The predicted yield for each run was determined by means of a modified $Y = Sx - By$ formula. This very simple and direct formula was developed at the Houma, Louisiana, Experiment Station and is based on the Winter-Carp retention formula.[5] As used in these studies, the formula was modified by the inclusion of the average pol and Brix extraction factors to read:

$$Y = Sx - By$$

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[5]George Arceneaux, "A simplified Method of Making Theoretical Sugar Yield Calculations," International Sugar Journal, XXXVII (1935), 264-265.

where: Y is the predicted yield, lbs. 96° Sugar/Ton of Gross Cane.

S is the Pol Extracted % Cane – Sample Mill.

x is 29.167 (a) (c) $\dfrac{\text{lbs. } 96^{\circ} \text{ Sugar}}{(\text{Ton Cane})\ (\%\ \text{Pol Extracted})}$

B is the Brix Extracted % Cane – Sample Mill.

y is 8.333 (b) (c) $\dfrac{\text{lbs. } 96^{\circ} \text{ Sugar}}{(\text{Ton Cane})\ (\%\ \text{Brix Extracted})}$

(a) is the Pol Extraction Factor.

(b) is the Brix Extraction Factor.

(c) is the boiling house efficiency.

The five-year Louisiana state average boiling efficiency (1957-1961) of 0.9659 was used in these studies.[6]

Value of the Shipment: The value of the shipment as determined from the predicted yield was calculated as follows:

$$V = Y/100 \times S.P.$$

where: V is the value of the shipment for sugar, \$/Gross Ton of Cane.

S. P. is the average price of raw sugar for a specified period (weekly or season's average) as quoted by the New Orleans

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[6] "Special Statistical Issue," The Sugar Bulletin, XL (1962), p. 254.

Sugar Exchange, $/Cwt. 96° raw sugar.

For these studies, the 1961 season's average price of 96° raw sugar of $6.3153/cwt. was used.[7]

<u>Cost of Cane for Sugar</u>: The cost of cane for sugar, which is in effect the share of the value of cane for sugar which accrues to the grower, was determined as follows:

$$C = V \times F$$

where: C is the cost of cane for sugar, $/Gross Cane.
F is the share of the returns for sugar (or the value of sugar) which accrue to the grower.

The share of the returns for sugar to a grower in the Audubon Sugar Factory freight area (a) was assumed to be 0.646 for standard cane, i.e., 12 per cent pol in normal juice. This factor was calculated from the 1961 crop commercially recoverable sugar table.[8] This table, which determines the bases for the Sugar Act payments, shows the predicted yield at the different levels of pol per cent normal juice. In calculating the yields, the Winter-Carp theoretical retention

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[7]Exhibit No. 6 to the 1961 Sugar Mill Letter No. 3 from the Louisiana Agricultural Stabilization and Conservation Service State Office dated February 26, 1962.

[8]"Determination of Commercially Recoverable Sugar for the 1961 Crop of Louisiana Sugar Cane," <u>The Sugar Bulletin</u>, XL (1962), p. 86.

formula and the preceding five-year state average normal juice extraction and boiling house efficiency are assumed.

Cost of Cane By Normal Juice Quality

To provide a comparison of the cost of cane by sample mill extraction, the cost was computed with the conventional normal juice pol and purity method. In these calculations a dry milling factor of 0.97 was assumed. The factory normal juice Brix is then determined as follows:

$$\text{Brix \% Normal Juice, Factory} = \text{Brix \% Crusher Juice} \times 0.97$$

It was also assumed that the factory washed its cane so that it was necessary to determine an "undiluted" crusher juice Brix from the sample mill juice Brix and a dilution compensation factor as follows:

$$\text{Brix \% ``Undiluted'' Crusher Juice} = \text{Brix \% Sample Mill Juice} \times \text{Dilution Compensation Factor}$$

Actually, the cane was not washed, and for these studies the dilution compensation factor was determined as the crop average of the daily ratio of the Brix of the crusher juice to the Brix of the sample mill juice. Normally, this factor is determined in weekly one hour tests on dry sugar cane.

Another assumption was made in determining the factory normal juice pol which is calculated as follows:

$$\text{Pol \% Normal Juice, Factory} = \text{Brix \% Normal Juice, Factory} \times \text{Purity of Dilute Juice}$$

In these studies, no maceration water was used in order to collect dry milling data. For this reason, the purity of the extracted juice was higher than it would be under commercial conditions. Consequently, an assumed dilute juice purity was calculated corresponding to the standard factory extraction which was discussed in the preceding section. The calculation was as follows:

$$\text{Purity of Dilute Juice} = \frac{\text{Pol Extracted \% Cane, Standard Factory}}{\text{Brix Extracted \% Cane, Standard Factory}}$$

By the use of sample mill factors, the growers' cane quality (the predicted normal juice pol and purity) is determined as the product of the sample mill inspections and the sample mill factors. These factors, which relate the sample mill to the factory juice inspections, were determined as follows for each run, and the crop average value was then calculated:

$$\text{Sample Mill Brix Factor} = \frac{\text{Brix \% Normal Juice, Factory}}{\text{Brix \% Sample Mill Juice}}$$

$$\text{Sample Mill Pol Factor} = \frac{\text{Pol \% Normal Juice, Factory}}{\text{Pol \% Sample Mill Juice}}$$

In commercial operation, these factors are a running five day average of the factors for the current day and the preceding four days.

The growers' cane quality (the predicted normal juice pol and purity) was then calculated as follows:

$$\text{Predicted Normal Juice Pol} = \text{Pol \% Sample Mill Juice} \times \text{Sample Mill Pol Factor}$$

$$\text{Predicted Normal Juice Brix} = \text{Brix \% Sample Mill Juice} \times \text{Sample Mill Brix Factor}$$

$$\text{Predicted Normal Juice Purity} = \frac{\text{Predicted Normal Juice Pol}}{\text{Predicted Normal Juice Brix}}$$

Standard cane was then calculated as follows:

$$\text{Standard Cane per Net Ton Cane} = \text{Quality (Pol) Factor} \times \text{Purity Factor}$$

Then:

$$\text{Cost of Cane, \$/Net Ton} = \text{Standard Cane per Net Ton Cane} \times \text{1961 Crop Payment for One Ton of Standard Cane}$$

The 1961 crop payment for one ton of standard cane in Freight Area (a) was $6.726.[9]

To make this cost comparable with that from the sample mill

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[9] "Exhibit No. 6 to - - -," Ibid.

extraction calculations, the above cost was converted to a gross cane basis as follows:

$$\text{Cost of Cane, \$/Gross Ton} = \text{Cost of Cane, \$/Net Ton} \times \frac{\text{Net Ton}}{\text{Gross Ton}}$$

Cost of Cane from Pol, Fiber, and Brix Per Cent Cane

Since previous studies at the Audubon Sugar Factory had dealt with evaluation of cane in terms of the cane quality itself as pol, fiber, and Brix per cent cane, it was felt that cane cost data based on this method of cane quality determination would be of interest. For this purpose, the correlations which were developed in the previous section relating the sample inspections to those of the factory were used. It will be recollected that these correlations were in the form $\hat{y} = a + bx$ where $\hat{y}$ and x were the respective predicted factory and the sample pol, fiber, or Brix per cane.

Predicted extraction was based on the standard extraction factors discussed previously, i.e., pol/fiber in bagasse and Brix/fiber in bagasse, and calculated as follows:

$$\text{Predicted Pol Extracted \% Cane} = \text{Predicted Pol \% Cane} - \left[\frac{\text{Pol}}{\text{Fiber}}\right]_{\text{Bagasse}} \times \text{Fiber \% Cane}$$

$$\text{Predicted Brix Extracted \% Cane} = \text{Predicted Brix \% Cane} - \left[\frac{\text{Brix}}{\text{Fiber}}\right]_{\text{Bagasse}} \times \text{Fiber \% Cane}$$

The predicted yield for each run was determined by means of $Y = Sx - By$, which was modified for this application as follows:

$$Y = Sx - By$$

where: Y is the predicted yield, lbs. 96° Sugar/Ton of Gross Cane.

S is the predicted pol extracted per cent cane.

x is $29.167\ (c)\ \dfrac{\text{lbs. } 96^\circ \text{ Sugar}}{(\text{Ton Cane})\ (\%\ \text{Pol Extracted})}$

B is the predicted Brix extracted per cent cane.

y is $8.33\ (c)\ \dfrac{\text{lbs. } 96^\circ \text{ Sugar}}{(\text{Ton Cane})\ (\%\ \text{Brix Extracted})}$

(c) is the boiling house efficiency.

The five year state average boiling house efficiency of 0.9659 was used in these studies.

The value of the shipment and the subsequent cost of cane were calculated in the same manner as in the cost calculations with the sample mill extraction method of cane evaluation.

Miscellaneous Data Evaluation

Among the criticisms for the normal juice method of cane quality determination are the use of a dry milling factor to convert the crusher juice Brix to that of the normal juice, and the dilution compensation factor by means of which an "undiluted" crusher juice Brix may be calculated from the corresponding sample mill inspection when wash water is applied to the cane in the carrier.

Dry Milling Factor: No macertaion water was applied to the factory mill in order that a dry milling factor could be determined for each run by means of the following calculation:

$$\text{Dry Milling Factor} = \frac{\text{Factory Normal Juice Brix}}{\text{Factory Crusher Juice Brix}}$$

According to the annual Sampling Testing and Reporting Procedure, a Louisiana factory may use the factor 0.97, or it may run a dry milling test to determine a factor. Of interest, then, is the reproducibility of the factor or the range which might be expected in the factor as determined from one test. For this purpose, the factors from all runs were averaged, and the 95 per cent confidence limits for one dry milling test were determined.

Dilution Compensation Factor: Recently, questions have been raised as to the value and the reproducibility of the dilution compensation factor, and plans have been formulated to run dilution compensation factor tests at several Louisiana factories during the 1962 crop. Unfortunately, these discussions took place after the completion of the plant tests in this study. Among the factors which undoubtedly influence the dilution compensation factor are the method of removing the cane sample – whether by hand or mechanical grab – and the manner of milling the sample as the type of equipment, pressure on the rolls, etc. These factors were all constant during these studies. The cane was sampled by mechanical grab; the sample mill is a well-designed prototype of a commercial mill; and pressures simulating those of commercial operation were maintained on the mill. Thus the only variables operable which might affect the factor were the quality of the cane itself as the variety and degree of maturity, the weather as reflected by rainfall and subsequently wet cane, and the volume of trash accompanying the cane.

With the above considerations in mind, the dilution compensation factor was calculated for each run in the following manner:

$$\text{Dilution Compensation Factor} = \frac{\text{"Undiluted" Crusher Juice Brix}}{\text{Sample Mill Juice Brix}}$$

Since no wash water was applied to the cane in the carrier, the crusher juice was of course "undiluted."

From the daily run data, the average factor was determined, and the 95 per cent confidence limits for one dilution compensation factor test were subsequently calculated.

CHAPTER VIII

RESULTS AND DISCUSSION OF RESULTS

FACTORY VERSUS SAMPLE POL EXTRACTION

From the data of 23 runs, linear correlations were developed for each sample processing device relating the sample pol extraction to the factory extraction. The correlations took the form:

$$\hat{y} = a + bx$$

where: $\hat{y}$ is the predicted factory pol extraction, lbs. pol extracted per ton of cane.

x is the sample mill pol extraction, pol extracted per cent cane.

a and b are the intercept and the regression coefficient respectively.

The extraction data and a summary of the statistical analysis of the data are shown in Table VII. The degree of correlation and the accuracy of each device in predicting the factory extraction are summarized below:

TABLE VII

POL EXTRACTION CORRELATION
FACTORY VERSUS SAMPLE MILL

Basis: y = a + bx

Where: y is the factory extraction, lbs. pol extracted per gross ton of cane.
x is the sample mill extraction, pol extracted % cane.
a and b are the intercept and regression coefficient respectively.

Date (1961)	y	Farrel - 1	Farrel - 2	Screw Press	Box Press
Oct. 26	191.4	8.97	9.88	10.30	8.35
Oct. 30	190.4	8.92	9.93	10.31	8.74
Oct. 31	208.8	9.81	10.91	10.75	8.42
Nov. 2	209.2	9.45	10.81	11.31	8.72
Nov. 3	190.0	9.15	9.94	10.72	8.36
No. 6	182.2	9.02	9.79	10.42	8.81
Nov. 7	195.4	9.14	10.03	10.43	8.11
Nov. 9	194.8	9.24	10.37	10.45	8.41
Nov. 10	189.8	9.22	10.09	10.31	8.40
Nov. 13	182.4	8.43	9.54	9.33	7.36
Nov. 14	166.8	7.59	9.59	9.72	7.25
Nov. 16	168.4	7.95	8.30	9.09	7.42
Nov. 17	189.0	8.72	9.33	10.06	7.12
Nov. 20	188.2	8.88	9.59	10.89	7.51
Nov. 21	200.8	9.44	10.58	10.83	7.60
Nov. 27	184.4	8.55	9.25	10.09	7.42
Nov. 28	196.6	9.21	9.77	10.37	8.10
Nov. 30	210.8	10.12	10.99	11.49	8.65
Dec. 1	203.2	9.69	10.01	11.21	7.70
Dec. 4	203.6	9.48	10.62	11.06	7.87
Dec. 5	211.2	9.87	10.51	11.16	7.24
Dec. 7	208.8	9.81	10.69	11.27	7.59
Dec. 8	214.8	10.25	10.74	11.01	7.31
a	—	17.0	16.9	2.5	161.7
b	—	19.396	17.698	18.234	4.177
r	—	0.9600	0.8702	0.8676	0.1796
r^2	—	0.9216	0.7573	0.7527	0.0323

(Table continued on next page)

TABLE VII (cont'd)

POL EXTRACTION CORRELATION

FACTORY VERSUS SAMPLE MILL

	y	x Farrel - 1	Farrel - 2	Screw Press	Box Press
$s(\hat{y})$, lbs. pol	—	3.75	6.60	6.66	13.18
Coefficient of variation, %	—	1.9	3.4	3.4	6.8
95% confidence Limits at Avg., ±lbs. pol	—	7.9	14.0	14.1	27.9

Sample Mill	r	r^2	Coeff. of Variation, %	95% Conf. Limits of One Sample at the Run Avg. Ext., lbs. pol
Farrel-1	0.9600	0.9216	1.9	7.9
Farrel-2	0.8702	0.7573	3.4	14.0
Screw Press	0.8676	0.7527	3.4	14.1
Box Press	0.1796	0.0323	6.8	27.9

Of particular interest is the relatively high degree of correlation for the single milling in the Farrel mill. The 23 runs cover data from two laboratory sections, and in each section the Farrel-1 processing scheme showed the best correlation. The correlation coefficient r was 0.9248 for the first section and 0.9806 for the second section. It is of interest to compare the extraction as predicted from the Farrel-1 correlation with the actual factory extraction for the 23 runs. This is done in Table VIII.

The Farrel-2 and screw press correlation were reasonably good - particularly when compared to the degree of correlation achieved in the studies of the previous years. There is no reason evident why the degree of correlation with these processing schemes could not be improved with further study. The box press with a correlation coefficient of 0.1796 showed very poor accuracy. In order to provide an insight into the possible reasons for the difference in the accuracy of the various sample extraction devices, the individual factors which

TABLE VIII

ACTUAL VERSUS PREDICTED POL EXTRACTION

FARREL-1

Basis: $\hat{y} = 17.0 + 19.396\ x$

Where: $\hat{y}$ is the predicted factory extraction, lbs. pol extraction per gross ton of cane.

x is the sample mill extraction, pol extracted % cane.

Date 1961		x	Predicted $\hat{y}$	Actual y	Difference $y - \hat{y}$
Oct.	26	8.97	191.0	191.4	+ 0.4
	30	8.92	190.0	190.4	+ 0.4
	31	9.81	207.3	208.8	+ 1.5
Nov.	2	9.45	200.3	209.2	+ 8.9
	3	9.15	194.5	190.0	- 4.5
	6	9.02	192.0	182.2	- 9.8
	7	9.14	194.3	195.4	+ 1.1
	9	9.24	196.2	194.8	- 1.4
	10	9.22	195.8	189.8	- 6.0
	13	8.43	180.5	182.4	+ 1.9
	14	7.59	164.2	166.8	+ 2.6
	16	7.95	171.2	168.4	- 2.8
	17	8.72	186.1	189.0	+ 2.9
	20	8.88	189.2	188.2	- 1.0
	21	9.44	200.1	200.8	+ 0.7
	27	8.55	182.8	184.4	+ 1.6
	28	9.21	195.6	196.6	+ 1.0
	30	10.21	215.0	210.8	- 4.2
Dec.	1	9.69	205.0	203.2	- 1.8
	4	9.48	200.9	203.6	+ 2.7
	5	9.87	208.4	211.2	+ 2.8
	7	9.81	207.3	208.8	+ 1.5
	8	10.25	215.8	214.8	- 1.0
Average, lbs. pol per ton cane		-	-	-	$\pm$ 2.7

enter into the extraction calculation were statistically analyzed. Thus since pol extracted = juice extracted x pol per cent juice, the question arises as to how reproducible is the relationship between the factory and sample mill for each of the factors. For this purpose, the following relations were calculated by run for each sampling device:

$$\text{Juice Extraction Factor} = \frac{\text{Factory Mixed Juice Extraction \% Cane}}{\text{Sample Mill Juice Extraction \% Cane}}$$

$$\text{Pol \% Juice Factor} = \frac{\text{Pol \% Factory Mixed Juice}}{\text{Pol \% Sample Mill Juice}}$$

Table IX shows the juice extraction factors for each run and a summary of the statistical analysis of the total run data, while Table X shows the pol per cent juice factors and the statistical summary of the data. The statistical data are summarized below:

Standard Deviation, s(x)

-	Farrel-1	Farrel-2	Screw Press	Box Press
Juice Extraction Factor	0.0218	0.0175	0.0121	0.0828
Pol % Juice Factor	0.0185	0.0384	0.0310	0.0431

The reason then for the better pol extraction correlation for the single milling through the three-roll sample mill apparently lies in the

TABLE IX

ACCURACY OF THE SAMPLE MILL JUICE EXTRACTION

Basis: Juice Extraction Factor $= \frac{\text{Factory Mixed Juice \% Cane}}{\text{Sample Mill Juice \% Cane}}$

Date (1961)	Factory Mixed Juice % Cane	Sample Mill Juice % Cane			
		Farrel-1	Farrel-2	Screw Press	Box Press
Oct. 26	70.03	64.99	70.18	73.60	63.18
Oct. 30	70.22	60.99	70.32	73.64	63.02
Oct. 31	70.62	63.97	71.06	73.40	62.40
Nov. 2	70.99	62.84	69.72	73.48	62.06
Nov. 3	71.08	64.45	70.05	75.40	63.11
Nov. 6	72.27	65.74	72.35	74.89	65.19
Nov. 7	70.49	63.97	71.83	74.21	61.19
Nov. 9	70.56	64.81	72.66	73.87	60.65
Nov. 10	71.34	65.82	71.51	75.19	62.72
Nov. 13	73.26	64.53	73.27	76.59	61.44
Nov. 14	71.23	63.26	73.47	74.60	59.31
Nov. 16	71.85	65.08	71.72	75.93	59.50
Nov. 17	71.47	62.63	70.57	74.14	56.01
Nov. 20	70.58	63.54	67.96	75.47	56.57
Nov. 21	69.70	65.51	71.35	73.44	55.20
Nov. 27	69.16	61.65	68.39	73.11	57.80
Nov. 28	71.42	63.78	72.33	76.22	59.93
Nov. 30	68.06	61.07	66.04	70.43	52.56
Dec. 1	70.94	65.36	70.05	75.92	57.49
Dec. 4	68.61	60.06	68.30	71.33	52.28
Dec. 5	69.81	63.76	68.91	71.66	50.85
Dec. 7	66.84	60.00	65.60	68.22	51.76
Dec. 8	69.20	61.83	68.19	71.43	49.92

(Table IX continued on next page)

TABLE IX (cont'd)

ACCURACY OF THE SAMPLE MILL JUICE EXTRACTION

Date (1961)	Juice Extraction Factor Farrel - 1	Farrel - 2	Screw Press	Box Press
Oct. 26	1.0859	0.9979	0.9515	1.1084
Oct. 30	1.1513	0.9986	0.9536	1.1142
Oct. 31	1.1040	0.9938	0.9621	1.1317
Nov. 2	1.1283	1.0169	0.9649	1.1424
Nov. 3	1.1029	1.0147	0.9427	1.1263
Nov. 6	1.0993	0.9989	0.9650	1.1086
Nov. 7	1.1019	0.9813	0.9499	1.1520
Nov. 9	1.0887	0.9711	0.9552	1.1634
Nov. 10	1.0839	0.9976	0.9488	1.1374
Nov. 13	1.1353	0.9999	0.9565	1.1924
Nov. 14	1.1260	0.9695	0.9548	1.2010
Nov. 16	1.1040	1.0018	0.9463	1.2076
Nov. 17	1.1411	1.0128	0.9640	1.2760
Nov. 20	1.1108	1.0386	0.9352	1.2477
Nov. 21	1.0640	0.9769	0.9491	1.2627
Nov. 27	1.1218	1.0113	0.9460	1.1965
Nov. 28	1.1198	0.9874	0.9370	1.1917
Nov. 30	1.1145	1.0306	0.9663	1.2949
Dec. 1	1.0854	1.0127	0.9344	1.2340
Dec. 4	1.1424	1.0045	0.9619	1.3124
Dec. 5	1.0949	1.0131	0.9742	1.3729
Dec. 7	1.1140	1.0189	0.9798	1.2913
Dec. 8	1.1192	1.0148	0.9688	1.3862
Average Factor	1.1104	1.0028	0.9551	1.2109
Standard Deviation s(x) of the Factor	0.02184	0.01745	0.01206	0.08279

TABLE X

ACCURACY OF THE SAMPLE MILL POL PER CENT JUICE

Basis: Pol % Juice Factor = $\frac{\text{Factory Pol \% Mixed Juice}}{\text{Sample Mill Pol \% Juice}}$

Date (1961)	Factory Pol % Mixed Juice	Sample Mill Pol % Juice Farrel-1	Farrel-2	Screw Press	Box Press
Oct. 26	13.67	13.91	14.08	13.99	13.22
Oct. 30	13.56	14.63	14.11	14.00	13.85
Oct. 31	14.78	15.34	15.36	14.65	13.49
Nov. 2	14.75	15.04	15.50	15.38	14.05
Nov. 3	13.37	14.19	14.19	14.21	13.24
Nov. 6	12.60	13.73	13.54	13.92	13.52
Nov. 7	13.85	14.29	13.97	14.05	13.25
Nov. 9	13.80	14.26	14.27	14.15	13.88
Nov. 10	13.30	14.01	14.11	13.71	13.40
Nov. 13	12.45	13.05	13.03	12.19	11.99
Nov. 14	11.71	12.00	13.05	13.03	12.24
Nov. 16	11.72	12.21	11.57	11.97	12.47
Nov. 17	13.22	13.92	13.22	13.56	12.71
Nov. 20	13.33	13.99	14.10	14.43	13.28
Nov. 21	14.40	14.41	14.82	14.75	13.77
Nov. 27	13.33	13.87	13.53	13.80	12.84
Nov. 28	13.76	14.44	13.51	13.60	13.52
Nov. 30	15.49	16.56	16.64	16.31	16.46
Dec. 1	14.32	14.83	14.29	14.77	13.38
Dec. 4	14.84	15.79	15.56	15.51	15.05
Dec. 5	15.13	15.48	15.26	15.57	14.24
Dec. 7	15.62	16.35	16.29	16.52	14.66
Dec. 8	15.52	16.58	15.75	15.41	14.63

(Table X continued on next page)

TABLE X (cont'd)

ACCURACY OF THE SAMPLE MILL POL PER CENT JUICE

(Date) 1961	Pol % Juice Factor Farrel-1	Farrel-2	Screw Press	Box Press
Oct. 26	0.9827	0.9709	0.9771	1.0340
Oct. 30	0.9269	0.9610	0.9686	0.9791
Oct. 31	0.9635	0.9622	1.0089	1.0956
Nov. 2	0.9807	0.9516	0.9590	1.0498
Nov. 3	0.9422	0.9422	0.9409	1.0098
Nov. 6	0.9243	0.9372	0.9059	0.9320
Nov. 7	0.9692	0.9914	0.9858	1.0453
Nov. 9	0.9677	0.9671	0.9753	0.9942
Nov. 10	0.9493	0.9426	0.9701	0.9925
Nov. 13	0.9540	0.9555	1.0213	1.0384
Nov. 14	0.9758	0.8973	0.8987	0.9567
Nov. 16	0.9599	1.0130	0.9791	0.9399
Nov. 17	0.9497	1.0000	0.9749	1.0401
Nov. 20	0.9528	0.9454	0.9238	1.0038
Nov. 21	0.9993	0.9717	0.9763	1.0458
Nov. 27	0.9611	0.9852	0.9659	1.0382
Nov. 28	0.9529	1.0185	1.0118	1.0178
Nov. 30	0.9354	0.9309	0.9497	0.9411
Dec. 1	0.9656	1.0021	0.9695	1.0703
Dec. 4	0.9398	0.9537	0.9568	0.9860
Dec. 5	0.9774	0.9915	0.9717	1.0625
Dec. 7	0.9554	0.9589	0.9455	1.0655
Dec. 8	0.9361	0.9361	1.0071	1.0608
Average Factor	0.9575	0.9646	0.9671	1.0174
Standard Deviation s(x) of the Factor	0.01846	0.03843	0.03104	0.04313

greater accuracy of the juice inspections. Why the accuracy of this factor for the multiple milling is less than that for the single milling is not clear. Since multiple milling gives an extraction severity approaching that of the factory, the reverse would be expected.

Some Comments on the Box Press

The box press correlation (correlation coefficient $r = 0.1899$), and the reproducibility of the juice extraction and pol per cent juice factors are quite poor. A reason for this became evident early in the test series. Throughout the series, the feed for the screw and box presses was prepared in the ensilage cutter. Of the total feed of about 170 pounds, about eight pounds was removed for the box press. The product from the ensilage cutter was quite coarse - varying considerably in size. In many cases, some of the prepared cane was too large to fit in the box press cylinder. For this reason, it was necessary to selectively charge the box press. In addition, the product from the ensilage cutter represented varying degrees of cane preparation - from fully shredded cane to portions of whole stalks. Whereas both the three-roll mill and the screw press continued the stalk and cell disintegration, the box press was capable of merely exerting simple pressure on the cane mat. The varying size and degree of disintegration all contributed to a non-uniform feed to the box press.

To test the reproducibility of the box press on a uniform feed quality, the cane was prepared in the cane chipper for a special run.

The chipper consists of a solid steel hub — rotating at 1160 rpm — in which knife blades are affixed in a line parallel to the axis of the hub. The product from the chipper is rather finely divided, ranging in size from about 1/4 to 1/2 inch cubes or quarter rounds. Because the chipper can be fed at the rate of only two to three stalks at a time, trashy samples are very difficult to handle. For this reason, this equipment was not used during the routine test runs.

About 100 pounds of chipped cane were prepared on the chipper. The chips were placed on the concrete payment and well mixed. 10 sub-samples were placed in capped cans for subsequent processing in the box press. To minimize loss by evaporation, the mixing and sub-sampling were done as rapidly as possible. The 10 sub-samples were then processed in the box press in a uniform manner. The pol extraction data and a summary of the statistical analysis of the data are shown in Table XI.

The coefficient of variation of 1.85 for the box press, as shown in Table XI, shows this equipment to be very reproducible when handling a uniform feed. The problem with the box press thus seems to be that of developing equipment to completely and uniformly reduce a large sample of cane to provide a sub-sample of about eight to ten pounds.

Possible Sources of Error in the Extraction Studies

In the 1958 reproducibility studies on the Farrel sample mill,

TABLE XI

REPRODUCIBILITY OF THE BOX PRESS WITH UNIFORM FEED QUALITY-POL EXTRACTION

Basis: Pol Ext. % Cane = Juice Ext. % Cane x Pol % Juice/100

Sample No.	Juice Extracted, % Cane	Pol % Juice	Pol Extracted, % Cane
1	63.82	11.81	7.54
2	65.34	11.83	7.73
3	65.30	11.97	7.82
4	63.67	11.66	7.42
5	64.13	11.67	7.48
6	63.88	11.96	7.64
7	65.55	11.82	7.75
8	64.63	11.77	7.61
9	64.39	11.92	7.68
10	64.17	11.79	7.57
Average, $\bar{x}$			7.62
Standard Deviation s(x)			0.141
Coefficient of Variation, %			1.85

samples of cane were collected and the stalks split lengthwise and composited into two sub-samples which were subsequently milled twice to determine the pol per cent cane. The data from seven such tests showed the Farrel mill to be very reproducible with a coefficient of variation of 1.29 per cent. The corresponding two sigma limits (twice the coefficient of variation) are 2.58 per cent. For a cane sample containing 200 pounds of pol per ton of cane, this represents approximate 95 per cent confidence limits for one sample of about 5.16 pounds per ton of cane.

The two sigma limits for the pol extraction correlations on the Farrel-1, Farrel-2 and screw press are 3.8, 6.8, and 6.8 per cent respectively. These correspond to the calculated 95 per cent confidence limits of 7.9, 14.0, and 14.1 pounds pol per ton of cane respectively at the average extraction level of 195 pounds pol per ton of cane.

In view of the previously demonstrated reproducibility of the Farrel sample mill, it is logical to review those factors which might have contributed to an accuracy in the correlations less than that shown in the reproducibility tests. Among these factors are the accuracy of the factory mill data which served as the bases for comparison, and the possible sources of error in the sampling procedure.

Accuracy of the Factory Mill Data: In calculating the factory mill material balance, the feed to the mill was calculated as the sum of the weights of the mixed juice plus bagasse. For each run, the feed as so determined was compared with the weight of cane as recorded from the cane scale on the derrick. The difference was noted as per cent of feed by weight of juice plus bagasse. Although extensive precautions were taken to minimize errors in the factory material balance, this difference averaged about two per cent and ranged from - 4.40 to + 3.60 per cent. Although all scales entering into the material balance were calibrated - including the cane scale, it was recognized that the cane scale was subject to error. Reproducibility in weight determinations was particularly difficult to attain on windy days. The effect of the wind on the derrick boom - and the subsequent error in the scale reading was quite noticeable.

Even admitting that the cane scale was not 100 per cent accurate, the recurring difference in the material balance indicated possible sources of error in the juice and bagasse balance. Because it was felt that certain inherent errors might be present in handling a small volume of feed, four bundles of cane were ground each run - rather than one or two as in previous studies. Four bundles were about the maximum which could be handled in the normal three hour laboratory period.

<u>The Sampling Procedure as a Source of Error</u>: A mechanical grab was removed from each of the four bundles. Each grab was placed on the platform and divided into four sub-samples, care being taken to

minimize loosening of trash and loss of extraneous material. The sub-samples from the four bundles were composited. One sub-sample was analyzed for trash. One each served as feed to the Farrel-1 and Farrel-2 procedure, and the fourth sub-sample was prepared in the ensilage cutter as feed to the screw press and box press - the latter device taking about eight pounds of chopped cane.

The final samples to the various sample processing devices represented about one per cent of the feed to the factory and ranged from about 0.8 to 1.1 per cent. The effect of sample size on the precision of the pol and fiber tests was discussed in the section **SIZE OF SAMPLE VERSUS PRECISION OF THE CANE QUALITY TESTS** of Chapter IV. In this section it was noted that the two and the five per cent samples each gave the best correlation for their particular run series. Based on this observation, it could well be argued that the size of samples in the current run series was too small to achieve the precision which is desired in this type of study. Unfortunately, in increasing the volume of feed to the factory to minimize errors in the factory material balance, a limitation was encountered in the volume of sample which could be handled. One per cent of the factory feed was about the maximum which could be handled as limited by the space, equipment, and personnel. It is noted that even a one per cent sample is larger than is normally handled by a commercial factory. The problem appears to be that of providing equipment to take a larger sample and to reduce and sub-sample the charge to provide a feed for the sample processing equipment.

In view of the problems of the factory material balance and of the sampling procedure, the correlations as developed for the Farrel mill and the screw press appear to be unusually accurate.

Juice Deterioration in the Screw Press: During the preliminary runs which were devoted to "running in" the sample processing equipment and procedure, the bagasse initially leaving the screw press at the beginning of each run had a perceptible odor of fermented juice. This was attributed to the bagasse which remained in the cage of the press after each run. This problem appeared to be solved by running several stalks of cane through the press prior to each run to purge the cage.

Juice Dilution in the Box Press: At the end of every run, the Farrel mill and box press were hosed down with water to remove juice and bagasse chips. On several occasions prior to a run, residual water was found on the box press base plate and false bottom. This undoubtedly contributed to the lower juice density and pol in juice for this device as will be noted from the juice inspection in the data sheets (Appendix). Any such error as this would of course be accentuated because of the small volume of feed to the press.

FACTORY VERSUS SAMPLE BRIX EXTRACTION

Correlations of the y = a + bx type were derived which related the sample Brix extraction to that of the factory in a manner similar to the pol extraction studies. The extraction data and a summary of the statistical analysis of the data are shown in Table XII. A rather poor degree of correlation and accuracy resulted as shown by the following summary of the statistical data:

Sample Mill	r	r^2	Coeff. of Variation %	95% Coef. Limits of One Sample at the Run Avg. Ext., lbs. Brix
Farrel-1	0.5927	0.3513	2.6	13.7
Farrel-2	0.7313	0.5349	2.2	11.6
Screw Press	0.6553	0.4294	2.4	12.9
Box Press	0.1899	0.0361	3.1	16.7

The reason for the poor correlation appears to lie in a combination of factors - namely the use of the hydrometer for soluble solids determination and a fairly high incidence of rainfall during the crop with the accompanying trash and extraneous material in the cane which was delivered to the factory.

The effect of suspended sediment on the hydrometer spindle is, of course, to buoy up the spindle, thereby giving a higher reading and a

TABLE XII

BRIX EXTRACTION CORRELATION

FACTORY VERSUS SAMPLE MILL

Basis: $y = a + b x$

Where: y is the factory extraction, lbs. Brix extracted per gross ton of cane.
x is the sample mill extraction, Brix extracted % cane.
a and b are the intercept and regression coefficient respectively.

Date (1961)	y	x: Farrel-1	x: Farrel-2	x: Screw Press	x: Box Press
Oct. 26	246.0	11.48	12.56	13.54	10.92
Oct. 30	254.2	11.18	12.78	13.68	11.24
Oct. 31	264.2	12.18	13.51	14.10	10.90
Nov. 2	257.8	11.38	13.15	14.01	11.06
Nov. 3	248.8	11.45	12.44	13.33	10.49
Nov. 6	247.8	11.36	12.46	13.18	10.81
Nov. 7	248.8	11.26	12.54	13.21	10.17
Nov. 9	242.4	11.33	12.90	13.38	10.17
Nov. 10	247.2	11.49	12.75	13.11	10.59
Nov. 13	242.4	10.78	12.46	12.40	9.62
Nov. 14	251.6	10.15	12.22	12.28	9.14
Nov. 16	222.6	10.36	11.28	11.95	9.29
Nov. 17	245.6	10.70	11.78	12.51	8.77
Nov. 20	251.8	11.20	12.02	13.62	9.37
Nov. 21	251.8	11.56	13.07	13.38	9.26
Nov. 27	244.2	11.12	12.32	13.50	9.78
Nov. 28	240.0	11.03	12.25	12.99	9.69
Nov. 30	247.8	11.90	12.80	13.75	9.66
Dec. 1	251.0	11.62	12.35	13.61	9.28
Dec. 4	247.6	10.90	12.63	13.59	9.09
Dec. 5	253.8	11.53	12.53	13.32	8.71
Dec. 7	248.8	11.38	12.40	13.14	8.89
Dec. 8	256.4	11.69	12.71	12.98	8.51

(Table XII continued on next page)

TABLE XII (cont'd)

BRIX EXTRACTION CORRELATION

FACTORY VERSUS SAMPLE MILL

	y	x: Farrel-1	Farrel-2	Screw Press	Box Press
a	—	135.5	92.8	122.3	230.9
b	—	10.022	12.425	9.518	1.783
r	—	0.5927	0.7313	0.6553	0.1899
r^2	—	0.3513	0.5349	0.4294	0.0361
$s(\hat{y})$, lbs. pol	—	6.45	5.46	6.05	7.86
coefficient of variation, %	—	2.6	2.2	2.4	3.1
95% confidence Limits at Avg., ±lbs. pol	—	13.7	11.6	12.9	16.7

lower calculated purity than the true values. This effect was graphically illustrated in the Run of November 14. The original factory data sheet shows the comment "Considerable floating material in the crusher and mixed juice samples." The purity of the crusher, mixed, and last mill juice were subsequently calculated to be 62.10, 62.28, and 72.50 respectively. Although efforts were made to decant off the clear solution for a solids determination – when a large volume of suspended material was evident in the hydrometer cylinder – quite often the clear solution which remained from the cylinder and the sample can was inadequate for a satisfactory solids determination. Towards the end of the crop, the refractometer was used in parallel with the Brix spindle; however, the refractometer data covered only a small part of the whole run series.

The Brix Spindle versus the Refractometer

Informal comparative instrument precision tests were run to determine the 95 per cent confidence limits of one solids determination by Brix spindle and by refractometer. These tests were conducted on clean juice, i.e., juice which was observed to be free of suspended sediment. The results are summarized below:

Instrument	95% Confidence Limits of One Determination, + or - % Brix
Hydrometer	0.13
Refractometer	0.22

Interestingly enough, on juice free from suspended sediment, the hydrometer spindle showed a higher instrument precision than the refractometer. This was probably to be expected, for while the Brix spindle is graduated to 0.1° Brix, the Bausch and Lomb Abbe refractometer, which was used in these studies, is graduated to 0.5° Brix. The more precise sugar refractometer which was not used in these studies has an accuracy of about 0.02° Brix.

Insufficient refractometer data were collected to permit a comparison with the hydrometer when handling trashy cane. Such a study is planned during the 1962 crop in which the hydrometer will be compared with the standard and the precision refractometer on centrifuged and uncentrifuged juice.

SAMPLE JUICE EXTRACTION OR SAMPLE FIBER AS A MEASURE OF FACTORY JUICE EXTRACTION

Single variable linear correlations were developed between the factory juice extraction and the sample mill juice extraction. Similar correlations were developed in which the sample fiber per cent cane was the dependent variable. These data and a summary of the statistical analysis of the data are shown in Table XIII. The degree of correlation between the factory juice extraction and the sample mill juice extraction and the sample fiber is shown below:

TABLE XIII

SAMPLE MILL JUICE EXTRACTION OR SAMPLE FIBER AS A MEASURE OF FACTORY JUICE EXTRACTION

Basis: $y = a + bx$

Where: y is the factory juice extraction % cane.
x is the sample mill juice extraction % cane or sample fiber % cane.
a and b are the intercept and regression coefficient respectively.

Date (1961)	y	Farrel-2, x = Sample: Juice Extraction	Farrel-2, x = Sample: Fiber	Screw Press, x = Sample: Juice Extraction	Screw Press, x = Sample: Fiber
Oct. 31	70.62	71.06	13.79	73.40	14.23
Nov. 2	70.90	69.72	14.59	73.48	14.32
3	71.08	70.05	14.10	75.40	14.08
6	72.27	72.35	10.94	74.89	14.29
7	70.49	71.83	10.03	74.21	14.03
9	70.56	72.66	12.51	73.87	14.08
10	71.34	71.51	13.22	75.19	14.16
13	73.26	73.27	11.76	76.59	12.60
14	71.23	73.47	12.54	74.60	13.76
16	71.85	71.72	12.68	75.93	12.98
17	71.47	70.57	13.18	74.14	13.21
20	70.58	67.96	13.79	75.47	13.73
21	69.70	71.35	12.90	73.44	13.56
27	69.16	68.39	15.09	73.11	15.14
28	71.42	72.33	13.15	76.22	14.45
30	68.06	66.04	15.97	70.43	16.17
Dec. 1	70.94	70.05	13.66	75.92	13.49
4	68.61	68.30	14.71	71.33	15.55
5	69.81	68.91	14.42	71.66	14.45
7	66.84	65.60	15.70	68.22	16.49
8	69.20	68.19	14.27	71.43	14.97
r		0.8348	0.7102	0.9094	0.8676
r^2		0.6970	0.5044	0.8270	0.7528
$s(\hat{y})$, Juice % Cane		0.797	1.069	0.602	0.755
Coefficient of Variation, %		1.13	1.52	0.86	1.07

	Factory Juice Extraction % Cane as a Function of: Sample Mill Juice Extraction % Cane	Sample Fiber % Cane
Farrel-2		
r	0.8348	0.7102
Coefficient of Variation, %	1.13	1.52
Screw Press		
r	0.9094	0.8676
Coefficient of Variation, %	0.86	1.07

Because of the coarse nature of the bagasse from the Farrel single milling, no fiber data were collected for this means of processing.

As the above data show, both the Farrel-2 and screw press juice extraction showed a better correlation with the factory juice extraction than did the fiber per cent cane of the corresponding samples.

The beneficial effect of a high degree of bagasse preparation on the subsequent fiber determination is well shown in the correlation coefficient for the screw press fiber of 0.8676 compared to that of 0.7102 for the Farrel-2. The bagasse from the screw press was well pulverized and easily handled in subsequent inspections. By contrast the bagasse from the double milling in the Farrel mill was quite coarse and non-uniform in size.

The fiber determinations were by the conventional method of drying the bagasse in a Dietert Moisture Teller to determine the moisture. The fiber was calculated in the routine manner:

$$\text{Fiber \% Bagasse} = 100.00 - (\text{Brix} + \text{Moisture}) \text{ \% Bagasse}$$

It is quite possible that a higher degree of precision is possible by the direct method of fiber determination which consists of washing a bagasse sample for a period of 24 hours to completely remove soluble solids, and then drying the sample.

The results with the screw press suggest that with a well and uniformly pulverized bagasse, and a more rigorous method of fiber determination, the correlation of sample fiber with the factory juice extraction might approach that of the sample mill juice extraction. Such refinements as this, of course, require additional time, personnel, and equipment in the laboratory.

It appears logical to conclude that in those methods of cane quality determination which incorporate fiber in the evaluation, adequate means should be provided for thoroughly and uniformly disintegrating the cane – for the cold water extraction process – or the bagasse – for the three-roll sample mill.

SAMPLE VERSUS FACTORY

POL, FIBER, AND BRIX PER CENT CANE

As noted in the previous chapter, preceding studies on cane quality determination at the Audubon Sugar Factory have involved evaluation of the cane in terms of the pol and fiber in the cane. In addition to this, the purity of the extracted juice from the sample was generally determined. In these studies, the sample inspections were subsequently compared with those of the factory.

Although the purpose of the current studies was to compare the sample mill and factory extraction, complete cane inspections were developed for the factory and sample data. With these data it was thus possible to determine single variable linear correlations between the sample and factory cane inspections. Table XIV shows the data for pol, fiber, and Brix per cent cane as well as a summary of the statistical data. Similar data are presented for the screw press in Table XV. The correlation coefficients are shown below:

	Correlation Coefficient, r	
	Farrel-2	Screw Press
Pol % Cane	0.8667	0.8738
Fiber % Cane	0.6555	0.8755
Brix % Cane	0.6807	0.7317

TABLE XIV

FARREL-2 VERSUS FACTORY

POL, FIBER AND BRIX PER CENT CANE

Basis: $y = a + bx$

Where: y is the factory pol, fiber, or Brix % cane.
x is the Farrel-2 pol, fiber, or Brix % cane.
a and b are the intercept and regression coefficient respectively.

Date (1961)	Pol % Cane y	Pol % Cane x	Fiber % Cane y	Fiber % Cane x	Brix % Cane y	Brix % Cane x
Oct. 31	12.15	12.63	14.15	13.79	15.37	15.64
Nov. 2	12.30	12.67	13.89	14.59	15.16	15.43
3	10.90	11.55	14.06	14.11	14.28	14.45
6	10.40	11.18	13.28	10.94	14.14	14.23
7	11.55	11.54	14.00	10.03	14.65	14.42
9	11.55	12.10	13.84	12.51	14.45	15.00
10	10.97	11.69	13.61	13.22	14.30	14.78
13	10.32	10.98	11.96	11.76	13.71	14.34
14	9.98	11.05	13.92	12.54	14.80	14.09
16	10.14	9.72	12.35	12.68	13.41	13.22
17	10.80	10.65	13.30	13.18	14.11	13.46
20	10.99	11.34	13.80	13.79	14.69	14.23
21	12.10	12.41	13.38	12.90	15.19	15.33
27	10.64	10.60	14.79	15.09	14.22	14.10
28	11.28	11.14	13.52	13.15	14.08	13.97
30	11.91	13.33	15.60	15.97	14.20	15.53
Dec. 1	11.83	11.73	13.56	13.66	14.67	14.48
4	12.07	12.54	14.55	14.71	14.78	14.92
5	12.24	12.42	14.07	14.42	14.97	14.80
7	12.69	12.87	14.84	15.70	15.21	14.93
8	12.45	12.36	14.56	14.27	14.96	14.64
Average	11.39	11.74	13.86	13.48	14.54	14.57
a		2.04		8.89		6.40
b		0.7968		0.3685		0.5589
r		0.8667		0.6555		0.6807
r^2		0.7500		0.4297		0.4733
$s(\hat{y})$		0.4230		0.6252		0.3850
Coefficient of variation, %		3.71		4.51		2.65

TABLE XV

SCREW PRESS VERSUS FACTORY

POL, FIBER, AND BRIX PER CENT CANE

Basis: y = a + b x

Where: y is the factory pol, fiber, or Brix % cane.

x is the screw press pol, fiber, or Brix % cane.

a and b are the intercept and regression coefficient respectively.

Date	Pol % Cane		Fiber % Cane		Brix % Cane	
(1961)	y	x	y	x	y	x
Oct. 31	12.15	12.28	14.15	14.23	15.37	16.13
Nov. 2	12.30	12.81	13.89	14.32	15.16	15.87
3	10.90	11.88	14.06	14.08	14.28	14.79
6	10.40	11.63	13.28	14.29	14.14	14.71
7	11.55	11.87	14.00	14.03	14.65	15.03
9	11.55	11.94	13.84	14.08	14.45	15.29
10	10.97	11.46	13.61	14.16	14.30	14.57
13	10.32	10.26	11.96	12.60	13.71	13.63
14	9.98	11.08	13.92	13.76	14.80	14.00
16	10.14	10.18	12.35	12.98	13.41	13.39
17	10.80	11.33	13.30	13.21	14.11	14.09
20	10.99	12.22	13.80	13.73	14.69	15.28
21	12.10	12.33	13.38	13.55	15.19	15.23
27	10.64	11.08	14.79	15.14	14.22	14.82
28	11.28	11.90	13.52	14.45	14.08	14.01
30	11.91	13.24	15.60	16.17	14.20	15.85
Dec. 1	11.83	12.39	13.56	13.49	14.67	15.04
4	12.07	12.38	14.55	15.55	14.78	15.20
5	12.24	12.85	14.07	14.45	14.97	15.34
7	12.69	13.26	14.84	16.49	15.21	15.46
8	12.45	12.37	14.56	14.97	14.96	14.58
Average	11.39	11.94	13.86	14.27	14.54	14.87
a		1.13		3.47		6.88
b		0.8596		0.7277		0.5154
r		0.8738		0.8755		0.7317
r^2		0.7636		0.7657		0.5354
$s(\hat{y})$		0.4113		0.4012		0.3619
Coefficient of variation, %		3.61		2.89		2.49

As in the preceding section covering factory juice extraction as a function of fiber per cent cane and of sample mill juice extraction, fiber by means of the screw press shows a better correlation than does fiber by means of Farrel-2. The relatively poor correlation for Brix is probably to be expected in view of the possible sources of error with the hydrometer.

For purposes of comparison, the corresponding statistical data for pol per cent cane, which were developed in Chapter V from Paul's 1958 studies, are shown below. In the 1958 studies, all samples were milled twice in the Farrel mill.

	Correlation Coefficient, r	
	Simple Mechanical Grab	Simple Multiple Grab
Pol % Cane	0.81	0.84

From these studies, it is evident that the degree of correlation for pol per cent cane of the current studies compares quite well with that of previous investigations.

COST OF CANE

Sample Mill Extraction

Since the procedure for determining the cost of cane by sample mill extraction is developed in the previous chapter, the procedure is reviewed briefly here and in subsequent cane cost discussion only as is necessary to develop the data. In addition, to permit a comparison of the cost of cane by sample mill extraction with the cost of cane using the pol, fiber, and Brix of the cane sample, the Farrel-2 data were used in these calculation since no fiber data were determined during the Farrel-1 studies.

Prior to determining the sample mill Brix and pol extraction factors, the factory Brix and pol extraction per cent cane were corrected to a standard extraction. In the case of pol per cent cane, the standard extraction was calculated by subtracting from the factory pol per cent cane the product of the factory fiber per cent cane and the standard extraction factor of 0.0712 parts of pol per part of fiber in bagasse. The standard extraction factor was the 1961 crop average of a selected group of Louisiana factories. Similar calculations were completed for the standard factory Brix extraction. These data and the bases for the calculations are shown in Table XVI.

The sample mill pol and Brix extraction factors which relate the sample mill and the factory standard pol and Brix extraction were then calculated from the daily run data. From the daily data, the crop average factors were determined. These data are shown in Table XVII.

The average Brix and pol extraction factors were incorporated into the Y = Sx − By formula to determine the daily predicted yield as lbs. of 96° sugar per ton of gross cane as shown in Table XVIII.

Finally, the value of the shipment for sugar was determined from the daily predicted yield and the average price of sugar for

TABLE XVI

STANDARD FACTORY EXTRACTION

COST OF CANE BY SAMPLE MILL EXTRACTION

Basis: Factory data corrected to standard extraction.
Standard extraction factors: Pol/Fiber in Bagasse = 0.07120
Brix/Fiber in Bagasse = 0.09766

$$\text{Standard Pol Extracted \% Cane} = \text{Pol \% Cane} - \left[\frac{\text{Pol}}{\text{Fiber}}\right]_{\text{Bagasse}} \times \text{Fiber \% Cane}$$

$$\text{Standard Brix} = \text{Brix \% Cane} - \left[\frac{\text{Brix}}{\text{Fiber}}\right]_{\text{Bagasse}} \times \text{Fiber \% Cane}$$

	Factory			Standard		
Date (1961)	Pol % Cane	Brix % Cane	Fiber % Cane	Pol Extracted % Cane	Brix Extracted % Cane	Purity
Oct. 31	12.15	15.37	14.16	11.14	13.99	79.66
Nov. 2	12.30	15.16	13.90	11.31	13.80	81.94
3	10.90	14.28	14.06	9.90	12.91	76.69
6	10.40	14.14	13.27	9.46	12.84	73.61
7	11.55	14.65	14.00	10.55	13.28	79.45
9	11.55	14.45	13.84	10.57	13.10	80.66
10	10.97	14.30	13.61	10.00	12.97	77.10
13	10.20	13.55	11.96	9.35	12.38	75.50
14	9.98	14.80	13.92	8.99	13.44	66.88
16	10.14	13.41	12.35	9.26	12.20	75.88
17	10.80	14.11	13.30	9.85	12.81	76.91
20	10.99	14.69	13.80	10.01	13.34	75.00
21	12.10	15.19	13.39	11.15	13.88	80.30
27	10.64	14.22	14.78	9.59	12.78	75.04
28	11.28	14.08	13.52	10.32	12.76	80.85
30	11.91	14.20	15.60	10.80	12.68	85.19
Dec. 1	11.83	14.67	13.56	10.87	13.35	81.41
4	12.07	14.78	14.55	11.03	13.36	82.60
5	12.24	14.97	14.07	11.24	13.60	82.66
7	12.69	15.21	14.84	11.63	13.76	84.54
8	12.45	14.96	14.55	11.41	13.54	84.30

TABLE XVII

SAMPLE MILL BRIX AND POL EXTRACTION FACTORS

COST OF CANE BY SAMPLE MILL EXTRACTION

Basis: $\text{Brix Extraction Factor} = \dfrac{\text{Factory Standard Brix Extracted \% Cane}}{\text{Sample Mill Brix Extracted \% Cane}}$

$\text{Pol Extraction Factor} = \dfrac{\text{Factory Standard Pol Extracted \% Cane}}{\text{Sample Mill Pol Extracted \% Cane}}$

Date (1961)	Factory Standard Pol Extracted % Cane	Sample Mill Pol Extracted % Cane	Pol Extraction Factor	Factory Standard Brix Extracted Factor	Sample Mill Brix Extracted % Cane	Brix Extraction Factor
Oct. 31	11.14	10.91	1.021	13.99	13.51	1.035
Nov. 2	11.31	10.81	1.046	13.80	13.15	1.050
3	9.90	9.94	0.996	12.92	12.44	1.038
6	9.46	9.79	0.966	12.84	12.46	1.031
7	10.55	10.03	1.052	13.28	12.54	1.059
9	10.57	10.37	1.019	13.10	12.90	1.015
10	10.00	10.09	0.991	12.97	12.75	1.017
13	9.35	9.54	0.980	12.38	12.46	0.994
14	8.99	9.59	0.937	13.44	12.22	1.099
16	9.26	8.30	1.116	12.20	11.28	1.082
17	9.85	9.33	1.056	12.81	11.78	1.088
20	10.01	9.59	1.043	13.34	12.02	1.110
21	11.15	10.58	1.054	13.88	13.07	1.062
27	9.59	9.25	1.037	12.78	12.32	1.037
28	10.32	9.77	1.056	12.76	12.25	1.042
30	10.80	10.99	0.982	12.68	12.80	0.990
Dec. 1	10.87	10.01	1.085	13.35	12.35	1.081
4	11.03	10.62	1.039	13.36	12.63	1.058
5	11.24	10.51	1.069	13.60	12.53	1.085
7	11.63	10.69	1.088	13.76	12.40	1.110
8	11.41	10.74	1.063	13.54	12.71	1.065
Average			1.032			1.054

TABLE XVIII

PREDICTED YIELD

COST OF CANE BY SAMPLE MILL EXTRACTION

Basis: $Y = Sx - By$

where: Y is the yield, lbs. 96° sugar/gross ton of cane.

S and B are the sample mill pol and Brix extracted % cane.

x is 29.167 (a) (c) lbs. 96° sugar/(ton cane) (% pol extracted).

y is 8.333 (b) (c) lbs. 96° sugar/(ton cane) (% Brix extracted).

(a) is the pol extraction factor (1.032), (b) is the Brix extraction factor (1.054), and (c) is the boiling house efficiency (0.9659).

Date (1961)	S	B	Y
Oct. 31	10.91	13.51	202.6
Nov. 2	10.81	13.15	202.7
3	9.94	12.44	183.5
6	9.79	12.46	178.9
7	10.03	12.54	185.2
9	10.37	12.90	192.1
10	10.09	12.75	185.2
13	9.54	12.46	171.7
14	9.59	12.22	175.2
16	8.30	11.28	145.6
17	9.33	11.78	171.3
20	9.59	12.02	176.9
21	10.58	13.07	196.7
27	9.25	12.32	164.4
28	9.77	12.25	180.1
30	10.99	12.80	210.9
Dec. 1	10.01	12.35	186.3
4	10.62	12.63	201.6
5	10.51	12.53	199.3
7	10.69	12.40	205.6
8	10.74	12.71	204.4

the 1961 crop as quoted in the Louisiana Sugar Exchange, Inc., New Orleans, Louisiana. From this value and assuming that 64.6 per cent of the sugar accrues to the grower, the cost of cane for sugar was calculated. These data are shown in Table XIX. The cost of cane is expressed as $/gross ton of cane.

Normal Juice Quality

The daily factory normal juice Brix was determined from the sample mill Brix, a dilution compensation factor of 1.022, and an assumed dry milling factor of 0.97. The dilution compensation factor of 1.022 was the average for the crop of the ratio of the factory crusher juice Brix and the Farrel-2 sample mill Brix. The daily factory pol per cent normal juice was calculated as the product of the normal juice Brix and the mixed juice purity. Since maceration water was not applied to the mills during the tests, the mixed juice purity was determined from the standard factory extraction data of Table XVI as the ratio of the standard pol extracted to the standard Brix extracted.

From the factory normal juice Brix and pol and the corresponding sample mill juice inspections, daily sample mill Brix and pol factors were developed. These factors relate the factory normal juice and the sample mill juice inspections. The daily factors were averaged to determine crop average sample mill Brix and pol factors of 0.991 and 0.970 respectively.

TABLE XIX

VALUE OF THE SHIPMENT AND COST OF CANE FOR SUGAR

COST OF CANE BY SAMPLE MILL EXTRACTION

Basis: V = Y/100 x S. P.

where: Y is the yield, lbs. 96^{o} sugar/ton of gross cane; S. P. is the selling price of raw sugar ($6.3153/cwt 96^{o} raw sugar).

C = V x F

where: C is the cost of cane for sugar, $/gross ton, and F is the distribution factor (0.646).

Date (1961)		Y	V	C
Oct.	31	202.6	12.794	8.265
Nov.	2	202.7	12.804	8.271
	3	183.5	11.586	7.485
	6	178.9	11.300	7.299
	7	185.2	11.698	7.557
	9	192.1	12.130	7.836
	10	185.2	11.696	7.556
	13	171.7	10.841	7.003
	14	175.2	11.062	7.146
	16	145.6	9.197	5.941
	17	171.3	10.820	6.990
	20	176.9	11.169	7.215
	21	196.7	12.424	8.026
	27	164.4	10.384	6.708
	28	180.1	11.376	7.349
	30	210.9	13.322	8.606
Dec.	1	186.3	11.786	7.614
	4	201.6	12.733	8.226
	5	199.3	12.585	8.130
	7	205.6	12.985	8.388
	8	204.4	12.911	8.341
Average				7.617

The crop average sample mill factors were then applied to the daily sample mill juice inspections to determine the hypothetical "grower's" normal juice Brix, pol, and purity. Appropriate quality (pol) and purity factors were determined from the 1961 Louisiana cane price determination, and from these data the grower's standard cane was derived. From the standard cane, the sample trash data, and the price of standard cane based on the 1961 crop average raw sugar price, it was then possible to determine the payment to the grower for his cane. These data are summarized in Table XX.

Pol, Brix, and Fiber Per Cent Cane

From the previously developed correlations between the sample mill and the factory pol, Brix, and fiber per cent cane – and the daily sample mill data – the predicted cane inspections were determined for each run. From these data, the predicted extraction was calculated based on the standard extraction factors of 0.07120 parts of pol per part of fiber in bagasse and 0.09766 parts of Brix per part of fiber in bagasse. The yield was subsequently developed from the $Y = Sx - By$ formula, and from this the value of the shipment and the cost of cane for sugar. These data are summarized in Table XXI.

Comparison of the Cost of Cane by the Different Methods

In Table XXII the daily cost of cane by the different methods of cane quality determination is tabulated. The cost of cane by the

TABLE XX

COST OF CANE
BY
NORMAL JUICE QUALITY

Date (1961)		Trash % Cane	Sample Mill Brix % Juice	Sample Mill Pol % Juice	Sample Normal Juice Brix % Juice	Sample Normal Juice Pol % Juice	Sample Normal Juice Purity	Standard Cane % Net Cane	Pavment to Grower, $/Gross Ton
Oct.	31	5.26	19.01	15.36	18.84	14.91	79.14	1.274	8.118
Nov.	2	4.15	18.85	15.50	18.68	15.05	80.57	1.293	8.336
	3	3.09	17.76	14.19	17.60	13.78	78.30	1.170	7.626
	6	1.48	17.22	13.54	17.07	13.15	77.04	1.107	7.336
	7	6.78	17.46	13.97	17.30	13.56	78.38	1.148	7.198
	9	11.00	17.76	14.27	17.60	13.86	78.75	1.181	7.069
	10	3.74	17.83	14.11	17.67	13.70	77.53	1.157	7.491
	13	1.76	17.01	13.03	16.86	12.65	75.03	1.049	6.932
	14	6.20	16.64	13.05	16.49	12.67	76.83	1.063	6.707
	16	13.00	15.72	11.57	15.58	11.23	72.08	0.907	5.307
	17	7.69	16.69	13.22	16.54	12.84	77.63	1.087	6.749
	20	4.37	17.69	14.10	17.53	13.69	78.09	1.161	7.468
	21	3.12	18.33	14.82	18.17	14.39	79.20	1.230	8.015
	27	4.30	18.01	13.53	17.85	13.14	73.61	1.076	6.926
	28	2.82	16.94	13.51	16.79	13.12	78.14	1.112	7.268
	30	4.85	19.38	16.64	19.21	16.16	84.12	1.417	9.069
Dec.	1	6.67	17.62	14.29	17.46	13.88	79.59	1.192	7.482
	4	7.32	18.49	15.56	18.32	15.11	82.48	1.311	8.173
	5	2.60	18.18	15.26	18.02	14.82	82.24	1.291	8.457
	7	7.62	18.90	16.29	18.73	15.82	84.46	1.392	8.650
	8	12.00	18.64	15.75	18.47	15.29	82.78	1.334	7.895
Average									7.444

TABLE XXI

COST OF CANE
BY
POL, FIBER, AND BRIX PER CENT CANE

Date (1961)	Sample Mill			Predicted Standard Factory Extraction		Yield, lbs. 96^{o} Sugar/ Ton Cane	Payment To Grower, $/Gross Ton
	Brix % Cane	Pol % Cane	Fiber % Cane	Brix % Cane	Pol % Cane		
Oct. 31	15.64	12.63	13.79	13.78	11.11	202.0	8.240
Nov. 2	15.43	12.67	14.59	13.63	11.12	203.7	8.311
3	14.45	11.55	14.11	13.10	10.24	182.9	7.463
9	15.00	12.10	12.51	13.46	10.72	193.6	7.899
10	14.78	11.69	13.22	13.32	10.38	185.0	7.546
13	14.34	10.98	11.76	13.12	9.85	171.9	7.012
14	14.09	11.05	12.54	12.95	9.88	174.0	7.100
16	13.22	9.72	12.68	12.47	8.82	148.0	6.038
17	13.46	10.65	13.18	12.58	9.55	167.8	6.847
20	14.23	11.34	13.79	12.99	10.09	179.6	7.327
21	15.33	12.41	12.90	13.64	10.96	199.0	8.117
27	14.10	10.60	15.09	12.87	9.46	163.0	6.648
28	13.97	11.14	13.15	12.87	9.94	176.5	7.201
30	15.53	13.33	15.97	13.64	11.61	217.2	8.863
Dec. 1	14.48	11.73	13.66	13.13	10.40	187.3	7.640
4	14.92	12.54	14.71	13.34	11.01	202.8	8.274
5	14.80	12.42	14.42	13.28	10.93	201.0	8.199
7	14.93	12.87	15.70	13.31	11.25	209.7	8.541
8	14.64	12.36	14.27	13.20	10.88	200.4	8.174
Average							7.655

TABLE XXII

COMPARISON OF THE COST OF CANE FOR SUGAR

Date (1961)		Run	Cost of Cane, $/Gross Ton: Normal Juice Quality	Cost of Cane, $/Gross Ton: Sample Mill Juice Extraction	Cost of Cane, $/Gross Ton: Pol Fiber and Brix % Cane	% of Average: Normal Juice Quality	% of Average: Sample Mill Juice Extraction	Sample Mill Juice Extraction % Cane
Oct.	31	1	8.118	8.265	8.240	107.7	108.5	71.06
Nov.	2	2	8.336	8.271	8.311	110.6	108.6	69.72
	3	3	7.626	7.485	7.463	101.2	98.3	70.05
	6	4	7.336	7.299	—	97.3	95.8	72.35
	7	5	7.198	7.557	—	95.5	99.2	71.83
	9	6	7.069	7.836	7.899	93.8	102.9	72.66
	10	7	7.491	7.556	7.546	99.4	99.2	71.51
	13	8	6.932	7.003	7.012	92.0	91.9	73.27
	14	9	6.707	7.146	7.100	79.7	93.8	73.47
	16	10	5.307	5.941	6.038	70.4	78.0	71.72
	17	11	6.749	6.990	6.847	89.5	91.8	70.57
	20	12	7.468	7.215	7.327	99.1	94.7	67.96
	21	13	8.015	8.026	8.117	106.3	105.4	71.35
	27	14	6.926	6.708	6.648	91.9	88.1	68.39
	28	15	7.263	7.349	7.201	96.4	96.5	72.33
	30	16	9.069	8.606	8.863	120.3	113.0	66.04
Dec.	1	17	7.482	7.614	7.640	99.3	100.0	70.05
	4	18	8.173	8.226	8.274	108.4	108.0	68.30
	5	19	8.457	8.130	8.199	112.2	106.7	68.91
	7	20	8.650	8.388	8.541	114.8	110.1	65.60
	8	21	7.895	8.341	8.174	104.8	109.5	68.19
Average			7.537	7.617	7.655			70.25

method of pol, fiber, and Brix per cent cane of the sample approximates that by the method of sample mill extraction. For this reason, the following comparison is confined to the cost of cane by normal juice and by sample mill extraction.

In analyzing the cost of cane, two items are considered, i.e., (1) the factory crop average cost of cane by each method, and (2) the relationship of the cost of cane of different quality to the average cost by each method.

The crop average cost of cane for sugar by normal juice was \$7.537/gross ton of cane, while the cost by sample mill extraction was calculated to be \$7.617.[1] The higher yield as reflected by the latter method might be expected. The 1961 crop was rather unique in terms of the high cane quality throughout the state. Most factories reported a higher than average yield of raw sugar per unit of normal juice pol.

One of the primary differences in the two methods of cane quality evaluation is the quantity of extracted or extractable juice in the cane. While this factor does not enter into the normal juice method, it is a

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[1] One small refinement might be mentioned to avoid confusion. By law, the price to be paid for standard cane by factories in the Audubon Sugar Factory area includes the growers' share of the cost of transporting the raw sugar to the refinery. This is currently \$0.032/standard ton. While this item was included in the calculation of cost of cane by normal juice, such an adjustment was not made in computing the cost by sample mill extraction. In the latter method, the season's average cost of raw sugar without any adjustment for the freight differential was used.

significant factor in the sample mill extraction method. The relationship of the cost of cane of different quality to the average cost in terms of the volume of juice extracted in the sample mill is summarized below.

Cane Quality	Runs	Cost of Cane Per Cent of Factory Average: Normal Juice	Cost of Cane Per Cent of Factory Average: Sample Mill Juice Extraction
High Extracted Juice % Cane	4, 6, 8, 9, 15	92	96
Low Extracted Juice % Cane	12, 16, 18, 20, 21	110	107

In this comparison, the grower with a high sample juice extraction receives a premium for his cane with the sample mill juice extraction method, while the grower with a low juice extraction is penalized as compared to the normal juice method. It is interesting to note that the high juice content in the early part of the crop was accompanied by low juice quality in terms of the pol and purity of the juice. This appears to be the explanation for the relatively low percentage of average values with cane of a high juice extraction.

A comparison of the cost of cane was also made with data from informal plant scale tests at the Helvetia Sugar Cooperative during the 1960 crop. In these tests, every sample was analyzed by sample mill extraction as well as by the conventional normal juice quality. The results of this study for selected growers showed the factory average cost of cane by normal juice quality to be slightly higher than by sample mill juice extraction.

While the juice extraction was determined for each sample, these data were not included in the final data summary. The comparison at the conclusion of these studies of the cost of cane of different quality to the average cost for each method was based on the pol and purity of the normal juice as the criterion of cane quality. From the quality of the normal juice, the standard cane value was calculated. High quality cane was determined to be of a high standard cane value or a low trash content. These data are summarized below.

Cane Quality	Cost of Cane Per Cent of Factory Average: Normal Juice	Cost of Cane Per Cent of Factory Average: Sample Mill Juice Extraction
High Standard Cane (Standard/Net Cane)	117	119
Low Trash	103	107
Low Standard Cane (Standard/Net Cane)	85	75
High Trash	88	84

These data show premiums accruing to the grower delivering high quality cane and penalities to the grower with low quality cane by the sample mill juice extraction method as compared to the normal juice method.

THE DRY MILLING AND DILUTION COMPENSATION FACTORS

The Dry Milling Factor

Data from the daily dry milling tests are shown in Table XXIII. The data were analyzed statistically to determine the 95 per cent confidence limits of one dry milling test. The confidence limits were calculated to be $\pm$ 0.047. Stating these results in terms of a dry milling test, if the true dry milling factor were 0.970, 95 times out of a 100 we would expect to get a test milling factor between 0.923 and 1.017.

The variability of the factor as stated statistically is evident from a glance at the tabular data. No apparent correlation is observable between the factor and the effects of trash, rain, or cane source. (Rainfall is shown in Table XXV.) A correlation is probably there, but the inherent variability of factor is so great that the effects of these variables are not perceptible.

The crop average dry milling factor is apparently not reproducible from year to year since the average for 1961 was 0.970 while that for 1960 was 0.947.

The Dilution Compensation Factor

The dilution compensation factor data as determined from the daily factory and sample mill data are shown in Table XXIV. The statistical analysis of the data showed 95 per cent confidence limits

TABLE XXIII

DRY MILLING FACTOR

Basis: Dry Milling Factor = $\frac{\text{Brix \% Normal Juice}}{\text{Brix \% Crusher Juice}}$

Date (1961)	Source of Cane	Trash % Gross Cane	Brix % Crusher Juice	Brix % Normal Juice	Dry Milling Factor
Oct. 31	LSU	5.26	19.43	18.70	0.962
Nov. 2	LSU	4.15	19.13	18.18	0.950
3	Outside	3.09	17.70	17.50	0.989
6	Outside	1.48	17.34	17.14	0.988
7	LSU	6.78	17.64	17.64	1.000
9	LSU	11.00	17.93	17.18	0.958
10	Outside	3.74	17.69	17.33	0.980
13	LSU	1.76	16.71	16.54	0.990
14	LSU	6.20	19.26	17.66	0.917(1)
16	St. Gabriel	13.00	15.97	15.49	0.970
17	St. Gabriel	7.69	17.09	17.19	1.006
20	St. Gabriel	4.37	18.02	17.85	0.991
21	St. Gabriel	3.12	18.10	18.06	0.998
27	St. Gabriel	4.30	18.48	17.65	0.955
28	St. Gabriel	2.82	17.77	17.08	0.961
30	St. Gabriel	4.85	19.39	18.21	0.939
Dec. 1	St. Gabriel	6.67	18.20	17.68	0.971
4	St. Gabriel	7.32	19.16	18.04	0.942
5	St. Gabriel	2.60	18.82	18.18	0.966
7	St. Gabriel	7.62	19.40	18.61	0.959
8	St. Gabriel	12.00	18.92	18.53	0.979
Average					0.970
Standard Deviation, s(x)					0.0227
Coefficient of Variation, %					2.34
95% Confidence Limits of one Test					± 0.047

(1) Considerable suspended material in crusher hydrometer jar.

TABLE XXIV

DILUTION COMPENSATION FACTOR

Basis: Dilution Compensation Factor = $\frac{\text{Brix \% Crusher Juice}}{\text{Brix \% Sample Mill Juice}}$

Date (1961)		Source of Cane	Trash % Gross Cane	Brix % Farrel-1 Juice	Brix % Crusher Juice	Dilute Compensation Factor
Oct.	31	LSU	5.26	19.04	19.43	1.020
Nov.	2	LSU	4.15	18.10	19.13	1.057
	3	Outside	3.09	17.77	17.70	0.996
	6	Outside	1.48	17.28	17.34	1.003
	7	LSU	6.78	17.60	17.64	1.002
	9	LSU	11.00	17.48	17.93	1.026
	10	Outside	3.74	17.46	17.69	1.013
	13	LSU	1.76	16.71	16.71	1.000
	14	LSU	6.20	16.04	19.26	1.201(1)
	16	St. Gabriel	13.00	15.92	15.97	1.003
	17	St. Gabriel	7.69	17.08	17.09	1.001
	20	St. Gabriel	4.37	17.62	18.02	1.023
	21	St. Gabriel	3.12	17.65	18.10	1.025
	27	St. Gabriel	4.30	18.05	18.48	1.024
	28	St. Gabriel	2.82	17.29	17.77	1.028
	30	St. Gabriel	4.85	19.48	19.39	0.995
Dec.	1	St. Gabriel	6.67	17.77	18.20	1.024
	4	St. Gabriel	7.32	18.16	19.16	1.055
	5	St. Gabriel	2.60	18.08	18.82	1.041
	7	St. Gabriel	7.62	18.96	19.40	1.023
	8	St. Gabriel	12.00	18.91	18.92	1.001
Average						1.027
Standard Deviation, s(x)						0.0438
Coefficient of Variation, %						4.26
95% Confidence Limits of one Test						±0.092

(1) Considerable suspended sediment in crusher hydrometer jar.

TABLE XXV

RAINFALL

Date (1961)		Rainfall, Inches LSU	St. Gabriel	Date (1961)		Rainfall, Inches LSU	St. Gabriel
Oct.	28	0		Nov.	21	0	0
	29	0			22	2.00	1.2
	30	0			23	0	T
	31	0			24	0	0
Nov.	1	0			25	0	0
	2	0			26	0	0
	3	0.92			27	0	0
	4	1.18			28	0	0
	5	0	0.1		29	0	0
	6	0	0		30	0	0
	7	0	0	Dec.	1	0	0
	8	0	0		2	0	0
	9	0	0		3	0	0
	10	0	0		4	0	0
	11	0	0		5	0	0
	12	0	0		6	0	0
	13	3.78	3.0		7	0	0
	14	1.74	T		8	0	0
	15	0	1.0				
	16	0	0.8				
	17	0	0				
	18	0	T				
	19	0	T				
	20	0	0				

of one dilution compensation factor test to be $\pm$ 0.092. Stating the results in terms of one test, if the true dilution compensation factor were 1.030, 95 times out of a 100 we would expect to get a test factor between 0.948 and 1.122.

Following the 1961 crop, there was considerable discussion in the industry regarding the variability and the reproducibility of the dilution compensation factor. As an outgrowth of these discussions, plant scale investigations are planned at several of the commercial raw sugar factories during the 1962 crop. The Audubon Sugar Mill will also cooperate in these studies. It is hoped that as a result of these investigations, some information may be collected regarding the effect on the factor and its reproducibility by such considerations as (1) the type of sample milling equipment - whether the sample mill is hydraulically loaded or fixed setting; (2) the size of the sample; (3) the method of collecting the sample, i.e., by hand or mechanical grab; (4) the method of feeding the sample mill as by a few stalks at a time or by means of a feed trough in which a uniform method of mill feeding can be approximated and the mill can be "loaded"; (5) the method of cane preparation prior to the mill tandem as knives or shredders or both; (6) the type of crusher or first mill; and (7) the effect of variety, condition of cane as plant or stubble - burned or unburned - and the effect of climatic conditions such as rain as it effects the wetness of the cane.

CHAPTER IX

CONCLUSIONS

General

A method of cane quality determination which is suitable to Louisiana and other areas with a high incidence of mechanical harvesting operations has been proposed and tested. This method — with applicable provisions for cane payment for sugar — includes the following key facets:

1. Withdrawing a sample from the cane shipment by mechanical grab or other means which should give a sample quality approaching that of the shipment itself.

2. a. Milling the sample in a hydraulically loaded three-roll sample mill — or other processing device which shows good extraction correlation with that of the factory mill tandem.

   b. In processing the sample with the three-roll sample mill, feeding the mill in such a manner as to simulate the loading on the factory mills. In these studies, the cane was laid in feed troughs to three to four layers depth, and the troughs were inserted in the sample mill feed chute and tilted so that the sample fed by gravity. In this manner the top roll floated, indicating that the full loading of the mill hydraulic system was on the bagasse mat.

3. Determining the sample mill pol and Brix extraction from the extracted juice quality and weight.
4. Determining pol and Brix extraction factors which relate the sample mill and factory extraction for a specified period of time.
5. Correcting the factory extraction to a standard extraction. On a state wide application of the system, the standard extraction would be the state factory average.
6. Determining the predicted recoverable sugar for each sample by means of the sample mill extraction data and the modified yield formula $Y = Sx - By$, where Y is the recoverable 96° sugar per ton of gross cane, and S and B are the sample pol and Brix extraction per cent cane.[1] The extraction factors, a

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[1]The original $Y = Sx - By$ formula was developed at the USDA Houma, Louisiana, Experiment Station.

standard boiling house efficiency, and the Winter-Carp retention formula are incorporated into the formula factors x and y.

7. Calculating the cost of cane (payment to the grower) for sugar by applying to the yield the price of sugar and a factor representing the state average split in returns for sugar between the grower and the factory.

This method of cane quality determination and its application in a cane payment system incorporate the following factors which are felt to be essential to a method of cane quality determination which is fair and equitable to the grower and the factory:

1. Cane quality is in terms of recoverable sugar in the shipment.

2. The factory <u>average</u> cane payment reflects the recoverable sugar in the cane from the area serving the factory and not an arbitrary state wide figure. The average cane quality is in effect that determined from the actual factory chemical control.

3. The recoverable sugar in the cane is based on standard factory extraction and boiling house efficiencies. These averages are to be determined from the corresponding state average figures. In this manner the

grower is not penalized for the inefficient factory, and the efficient factory can readily recover its investment to exceed the standard.

4. The split in the returns from sugar between the grower and the factory is based on the predicted recoverable sugar in the cane delivery and a standard distribution of the predicted returns from the sugar.

5. The sample mill extraction method enables the quality of cane from each grower to be assessed not alone on its juice quality but quantity as well. By using the actual juice extraction in the sample mill rather than the fiber content of the sample as a measure of the extractable juice in the cane, considerable cost and time is saved in the laboratory control.

Previous studies at the Audubon Sugar Factory have covered the method of withdrawing the sample and the effect of the size of the sample on the accuracy of the method of sampling. The use in the current studies of the mechanical grab and a sample approximating one per cent of the cane delivery were based on these prior investigations. While the sample by mechanical grab closely approximated that of the cane which was subsequently milled in the factory, there is a question as to whether one per cent of the total delivery is adequately representative of the total delivery to give the accuracy desired. This is discussed later.

In a like manner, the method of feeding the three-roll sample mill by means of feed troughs was developed in previous studies. This method of feeding very effectively loaded the mill - giving an extraction severity approaching that of the factory - and contributing materially to the high correlation observed between the factory and sample mill extraction.

Processing the Sample

The experimental phase of the current studies was devoted primarily to determining means of processing the sample which would be readily applicable to commercial scale application and which would give a high degree of correlation with the factory extraction. Throughout the test series, difficulty was experienced in attaining a wholly satisfactory factory material balance as indicated by a recurring difference in the weight of cane ground as determined from the weight of juice plus bagasse and the cane weight from the cane scales. Considering this, both single and double milling of the sample through the Farrel three-roll sample mill showed satisfactory correlation with the factory pol extraction, the correlation coefficients being 0.96 and 0.87 respectively. The screw press, an extruder type device for processing cotton seed, should also be satisfactory as a sample processing device - showing a correlation coefficient of 0.87.

In previous studies, the Farrel three-roll sample mill proved to be highly reproducible with a coefficient of variation of 1.29 per cent. This appears to bear out the consideration that better correlations would have been obtained with a more accurate factory material balance.

The correlation of Brix extraction for the sample processing devices and the factory tandem was considerably less satisfactory than that for pol extraction. This was attributed to problems of obtaining an accurate soluble solids determination with the hydrometer when grinding wet and trashy cane with a high incidence of field soil accompanying the shipment.

The correlation between the box press and the factory extraction was quite poor. However, on cane samples which were specially prepared for the press to a high degree of fineness and uniformity, the press showed good reproducibility with a coefficient of variation of 1.85 per cent. The problem then remains of devising equipment by means of which a cane sample of 100 pounds or greater can be reduced to small and uniform chip size from which an 8 to 10 pound sub-sample can be removed.

In studies which were devoted to determining the relative accuracy of the sample mill juice extraction versus the sample fiber as a measure of the juice extraction by the factory tandem, the sample mill juice extraction showed a higher correlation with the factory juice extraction than the fiber content of the sample. However, the accuracy of fiber as a means of predicting the juice extraction increased significantly with an increase in the degree of disintegration of the bagasse from the sample. The correlation coefficient relating the fiber in the screw press sample to the factory juice extraction was 0.87, while that for the double milling in the three-roll mill was 0.71. The bagasse as it came from the screw press was finely pulverized and easily handled in the subsequent laboratory bagasse moisture and pol determinations. By contrast, the bagasse from the sample mill was quite irregular in size, and some of the larger pieces could not be handled in the laboratory equipment.

In previous investigations at the Audubon Sugar Factory, studies were devoted to determining cane quality in terms of the pol, fiber, and Brix content of the cane. As a matter of interest in the current investigations, correlations were developed between the sample and the factory pol, fiber, and Brix per cent cane. These correlations for the three-roll sample mill compared favorably with those developed from the previous studies. The correlation for fiber with the screw press was considerably better than that by double milling in the three-roll mill.

Cost of Cane

In the 1961 pilot scale studies at the Audubon Sugar Factory and the 1960 plant scale investigation at Helvetia Sugar Cooperative, the factory average cost of cane for sugar by the sample mill juice extraction and by the normal juice method showed about the same order of magnitude. The sample mill juice extraction method gave a slightly higher average cost of cane in the 1961 pilot scale studies and a slightly lower average cost in the 1960 plant scale studies.

The sample mill extraction method was more responsive to differences in cane quality than the normal juice method. In the Audubon Sugar Factory studies, cane for which the samples had a high juice content showed a higher percentage of the average payment than the normal juice method, while cane with a low juice content showed a lower percentage of the average payment. Similar results were observed in the plant scale studies where cane with a high normal juice pol and purity or with a low trash content showed a higher than average payment than the normal juice method, while cane with a low normal juice pol and purity or a high trash showed a lower than average payment.

Future Work

Size of the sample: Previous studies at the Audubon Sugar Factory have shown that there is a significant improvement in the precision of the cane quality determination only as the sample size approaches two to five per cent of the total delivery. The samples of the typical Louisiana factory probably represent only 0.1 per cent of the cane deliveries. In these studies, a one per cent sample was used. The problem then appears to be that of devising means for disintegrating and uniformly mixing large samples to provide homogeneous sub-samples sufficiently small to be handled in the processing equipment, i.e., a feed of about 100 pounds for the three-roll sample mill and the screw press and eight pounds for the box press.

The Box Press

The box press costing $500 to $1000 represents considerably less investment than the hydraulically loaded three-roll sample mill – the cost of which may range from $6,000 to $15,000. The box press showed good reproducibility with specially prepared cane of small and uniform chip size, the coefficient of variation being 1.89 per cent. The problem is that as discussed in the previous section of providing means for preparing a sub-sample of satisfactory quality from a large sample of the shipment.

Boiling House Response in the Prediction of Recoverable Sugar: Considerable effort has been expended in devising means to predict the extraction response of a cane delivery through a sample analysis. The prediction of boiling house response is probably of equal importance where there is a high incidence of mechanical harvesting with accompanying burned and stale cane. To date, little has been done on this phase of cane quality evaluation.

Cane Payment Methods: While the subject of cane quality determination has been extensively reviewed in the literature, little is available on cane payment methods. With the world-wide trend toward establishing fair and equitable methods of cane payment, a study on this subject would provide much valuable information.

Cost of Factory and Farm Operations: Most of the recently developed cane payment methods base the cost of the cane – or the payment to the grower – on the relative factory and farm operating costs or investment. It is probably correct to say that there is generally little such data available in the first place, and when such studies are made there is a reluctance to publish the information. The sugar cane industry throughout the world can gain much by accelerating such studies and exchanging the general results of the studies.

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APPENDIX

NOMENCLATURE

General[1]

Trash: The leaves, tops, dead stalks, roots, soil, etc. delivered at the factory with the clean cane.

Fiber: The dry, water-insoluble matter in the cane.

Sucrose: The disaccharide known in chemistry as saccharose or cane sugar, $C_{12}H_{22}O_{11}$.

Note: Sucrose in solution is optically active and as such rotates plane polarized light. This property is used for the quantitative determination of sucrose. The instrument for such determinations is known as a saccharimeter. The 100^{o} point of a saccharimeter is usually based on the rotation of a definite weight (the so called normal weight) of chemically pure sucrose dissolved in water to 100 ml. at a specific temperature and polarized at the same temperature in a 200 mm. tube. As applied to sucrose containing substances, the operation of

[1]Except as noted, the terms in this section are as defined by the International Society of Sugar Cane Technologists (ISSCT).

determining the optical rotation of a normal weight of the substance is called direct polarization.

Pol: "Although cane products, and to a lessor extent beet products, contain other optically active substances besides sucrose, the technical accounting of sugar factories in many countries is still based on direct polarization, rather than the actual sucrose content. In some countries,....---, the figure obtained is nevertheless designated as 'sucrose'. In order to end the ensuing uncertainty, the International Society of Sugar Cane Technologists has adopted the term 'pol', defined as follows: 'The value determined by single or direct polarization of the normal weight in a saccharimeter.' This term is used in calculations as if it were a real substance."[2]

Note: Sucrose as defined in the previous definition is generally determined by the Clerget or double polarization method. In this method, a solution of the sugar bearing substance is inverted by enzyme or acid, and the optical activity of the inverted solution is compared with the direct polarization. Since the inversion is effective on the sucrose in the solution, this comparison enables the determination of the sucrose in the original substance.

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[2] C. A. Brown and F. W. Zerban, Sugar Analysis (Third Edition; New York: John Wiley & Sons, Inc., 1941), p. 1016.

In the dissertation chapter on cane quality determination, several of the literature references do not make too clear a distinction between pol and sucrose – the term sucrose as used being actually pol. In such references, the term sucrose is editorially qualified as apparent sucrose.

Brix: The per cent by weight of soluble solid matter as indicated by a Brix spindle or other densimetric device.

Refractometer Brix: The percent by weight of solids in solution as indicated by the sugar refractometer – or as derived from the refractive index and referred to tables of equivalent per cent sucrose and refractive index.

Dry Substance: The material remaining after drying the product examined to a constant weight.

True Purity: The percentage proportion of sucrose in the dry substance.

Gravity Purity: The percentage proportion of sucrose in the Brix solids.

Purity: The percentage proportion of pol in the Brix solids.

Absolute Juice: All the dissolved solids in the cane plus the total water of the cane – cane minus fiber.

Undiluted Juice: The juice expressed by the mills or retained in the bagasse – corrected for imbibition water.

Note: The term normal juice is still used in Louisiana and other areas of the western hemisphere.

Imbibition: The process in which water or juice is put on the bagasse to mix with and dilute the juice present in the latter. The water so used is termed imbibition water.

Note: The term maceration is commonly used instead of imbibition. This is so in Louisiana, and in these studies the term maceration is used in the sense of imbibition as defined. According to ISSCT definition, maceration is the process of steeping the bagasse in an excess of water.

First Expressed Juice: The juice expressed by the first two rollers of the tandem.

Note: This is thus the juice from a two-roll crusher – or the juice expressed by the cane and top roll of a three-roll crusher or mill.

Primary Juice: All juice expressed before dilution begins.

Secondary Juice: The diluted juice which – together with the primary juice – forms the mixed juice.

Last Expressed Juice: The juice expressed by the last two rolls of the tandem. (In the data tables – Appendix – the term Last Roll Juice is used.)

Mixed Juice: The juice sent from the crushing plant to the boiling house.

Residual Juice: The juice left in the bagasse — bagasse minus fiber.

Juice Extraction: The percentage weight of juice extracted by the mills.

Pol Extraction: Pol in mixed juice per cent pol in cane.

Sucrose Extraction: Sucrose in mixed juice per cent sucrose in cane.

Milling Loss: The percentage ratio of sucrose (or pol) in bagasse to fiber in bagasse.

Java Ratio: Pol (or sucrose) per cent cane divided by pol (or sucrose) per cent first expressed juice, and the resultant multiplied by 100.

Reduced Extraction: Sucrose (or pol) extraction reduced to a common standard basis of 12.5 per cent fiber in cane.

Retention: The percentage of sucrose (or pol) in the mixed juice that is recovered (or retained) in the commercial sugar.

Note: This definition is commonly in use in the Western Hemisphere — but at variance with the ISSCT definition where the term boiling house recovery is used. It is felt by many that the continued use of the term retention avoids confusion with the term recovery which is also applied to the overall "recovery" of sucrose (or pol) in commercial sugar, i.e., extraction times retention = recovery.

Boiling House Efficiency Number (BHE): The percentage relation between the actual retention and the theoretical retention as determined from an available sugar formula.

Note: The ISSCT recognizes the term Boiling House Performance to express the relationship between the actual and the theoretical boiling house recovery.

Statistical Data[3]

Regression Correlation and Miscellaneous

Correlation: The degree of association between one variable and another or between one variable and several others.

Regression: The nature of the relation between variables.

Regression Coefficient: When two variables can be correlated linearly, the regression coefficient is the slope of the line used to correlate the variables.

Goodness of the Correlation, r^2: The ratio of the sum of the squares removed by the correlation to the sum of the squares of the original data.

Correlation Coefficient, r: A measure of the correlation between two variables.

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[3]Except as noted, the terms in this section are as defined in Applied Statistics for Engineers (McGraw-Hill Book Company, Inc., 1958) by William Volk.

Standard Deviation of the Estimate, $s(\hat{y})$: A measure of the average deviation of the data points from the estimated values according to the correlation line.

Confidence Limits: A range of values that – on the basis of a given sample – has a specific probability of including the true mean.

Coefficient of Variation: The standard deviation divided by the arithmetic average (mean) and the resultant multiplied by 100.

Note: Although this term is used quite commonly in statistics, it is not included in Applied Statistics for Engineers.

SAMPLE CALCULATIONS

Material Balance Data

Basis: Two bundles of cane
No maceration water on the factory mill tandem
All inspections made in duplicate
Date: 12/5/62

1. Weight of Cane (Undiluted Juice + Bagasse), lbs.

   Factory = 17,864

   Farrel-2 = 99.4

2. Weight of Undiluted Juice, lbs.

   Factory = 12,470

   Farrel-2 = 68.5

3. Weight of Bagasse, lbs.

   Factory = 5,394

   Farrel-2 = 30.9

4. Brix Percent Undiluted Juice

   Brix by hydrometer and temperature correction from Cane Sugar Handbook, (Eighth Edition), page 728.

   Factory
   Uncorrected Brix = 17.80
   Brix % Undiluted Juice = 17.80 + 0.38 = 18.18

   Farrel-2
   Uncorrected Brix = 17.80
   Brix % Undiluted Juice = 17.80 + 0.38 = 18.18

5. Pol Percent Undiluted Juice

Horne's dry lead method and expansion of Schmitz's tables from Cane Sugar Handbook, (Eighth Edition), page 755.

Factory
Saccharimeter Reading = 62.3
Pol % Undiluted Juice = 15.13

Farrel-2
Saccharimeter Reading = 62.7
Pol % Undiluted Juice = 15.26

6. Purity

$$= \frac{\text{Pol \% Undiluted Juice}}{\text{Brix \% Undiluted Juice}} \times 100$$

Factory = 83.22

Farrel-2 = 83.94

7. Moisture Percent Bagasse

100 gram sample dried for 30 minutes in a Dietert Moisture Teller.

= Weight of Moist Sample − Weight of Dry Sample

Factory = 45.83

Farrel-2 = 46.30

8. Pol Percent Bagasse

Single digestion method using Spencer rotary digestor as described in Cane Sugar Handbook, (Eighth Edition), pp. 568-570.

Factory (Data from average of two samples)

a. Sample weight, g. 100

b. Total weight after digesting, g. 3967

c. Tare of capsule, g. 2903

d. Extract plus fiber, g. 1064

e. Fiber (assumed), g. 48

f. Extract, g. 1016

g. Saccharimeter reading of extract (400mm. tube) 4.2

h. Pol % extract 0.546

i. Weight of pol in extract, g. 5.55

j. Pol % Bagasse 5.55

Farrel-2 (by same procedure) = 6.14

9. Brix Percent Bagasse

Factory

$= \frac{\text{Pol \% Bagasse}}{\text{Last Roll Juice Purity}} \times 100 =$ 7.57

Farrel-2

$= \frac{\text{Pol \% Bagasse}}{\text{Undiluted Juice Purity}} \times 100 =$ 7.31

10. Fiber Percent Bagasse

= 100.00 – (Moisture + Brix)% Bagasse

Factory = 46.60

Farrel-2 = 46.39

11. Fiber, lbs.

= Weight of Bagasse x Fiber % Bagasse

Factory = 2514

Farrel-2 = 14.33

12. Brix in Undiluted Juice, lbs.

= Weight of Und. Juice x Brix % Und. Juice

Factory =	2267
Farrel-2 =	12.45

13. Pol in Undiluted Juice, lbs.

= Weight of Und. Juice x Pol % Und. Juice

Factory	1887
Farrel-2 =	10.45

14. Brix in Bagasse, lbs.

= Weight of Bagasse x Brix % Bagasse

Factory =	408
Farrel-2 =	2.26

15. Pol in Bagasse, lbs.

= Weight of Bagasse x Pol % Bagasse

Factory =	299
Farrel-2 =	1.90

16. Brix in Cane, lbs.

= Wt. of Brix in Und. Juice + Wt. of Brix in Bagasse

Factory =	2675
Farrel-2 =	14.71

17. Pol in Cane, lbs.

= Wt. of Pol in Und. Juice + Wt. of Pol in Bagasse

Factory =	2186
Farrel-2 =	12.35

18. Trash Percent Cane

Each bundle of cane was sampled by mechanical grab. From each grab, 20-30 lbs. of cane were removed and composited. (Care was taken to minimize loss of tops, leaves, and dirt.) The composite sample of all bundles was weighed and de-trashed, and the net cane was weighed. The difference between the weight of the gross and net cane was the weight of trash. The weight of trash divided by the weight of gross cane and multiplied by 100 yielded the Trash % Cane.

Gross Cane, lbs.	96.0
Net Cane, lbs.	93.5
Trash, lbs.	2.5

Trash % Cane 2.60

19. Undiluted Juice Percent Cane

$$= \frac{\text{Weight of Undiluted Juice}}{\text{Weight of Cane}} \times 100$$

Factory = 69.81

Farrel-2 = 68.91

20. Bagasse Percent Cane

$$= \frac{\text{Weight of Bagasse}}{\text{Weight of Cane}} \times 100$$

Factory = 30.19

Farrel-2 = 31.09

21. Brix Percent Cane

$$= \frac{\text{Weight of Brix in Cane}}{\text{Weight of Cane}} \times 100$$

Factory = 14.97

Farrel-2 = 14.80

22. Pol Percent Cane

$$= \frac{\text{Weight of Pol in Cane}}{\text{Weight of Cane}} \times 100$$

Factory =	12.24
Farrel-2 =	12.42

23. Fiber Percent Cane

$$= \frac{\text{Weight of Fiber in Bagasse}}{\text{Weight of Cane}} \times 100$$

Factory =	14.07
Farrel-2 =	14.42

24. Brix Extracted Percent Cane

$$= \frac{\text{Weight of Brix in Undiluted Juice}}{\text{Weight of Cane}} \times 100$$

Factory =	12.69
Farrel-2 =	12.53

25. Pol Extracted Percent Cane

$$= \frac{\text{Weight of Pol in Undiluted Juice}}{\text{Weight of Cane}} \times 100$$

Factory =	10.56
Farrel-2 =	10.51

26. Brix Extracted Percent Brix in Cane

$$= \frac{\text{Weight of Brix in Undiluted Juice}}{\text{Weight of Brix in Cane}}$$

Factory =	84.75
Farrel-2 =	84.64

27. Pol Extracted Percent Pol in Cane

$$= \frac{\text{Weight of Pol in Undiluted Juice}}{\text{Weight of Pol in Cane}}$$

Factory =	86.32
Farrel-2 =	84.62

Statistical Analysis

Single Variable Linear Regression Correlation – Factory Pol Extraction Versus Farrel Pol Extraction (Table XIV):

$$\hat{y} = a + bx$$

where: $\hat{y}$ is the predicted factory pol extraction, lbs. pol per ton of cane.

x is the Farrel-2 pol extraction, pol % cane.

a is the intercept.

b is the slope (regression coefficient).

y is the observed factory pol extraction, lbs. pol per ton of cane.

Number of Observations, n = 23

$\Sigma y = 4,481.00$	$\bar{y} = 194.83$	$\Sigma y^2 = 876,785.400$
$\Sigma x = 210.91$	$\bar{x} = 9.17$	$\Sigma x^2 = 1,943.279$
		$\Sigma xy = 41,269.884$

Sum of the Squares:

$$\Sigma' y^2 = \Sigma y^2 - \frac{(\Sigma y)^2}{n} = 3,769.710$$

$$\Sigma' x^2 = \Sigma x^2 - \frac{(\Sigma x)^2}{n} = 9.235$$

$$\Sigma' xy = \Sigma xy - \frac{(\Sigma x . \Sigma y)}{n} = 179.114$$

Slope:

$$b = \frac{\Sigma' xy}{\Sigma' x^2} = 19.396$$

Intercept:

$$a = \bar{y} - b\bar{x} = 16.967$$

Goodness of the Correlation.

$$r^2 = \frac{(\Sigma' xy)^2}{(\Sigma' x^2 . \Sigma' y^2)} = 0.9216$$

Correlation Coefficient:

$$r = (r^2)^{1/2} = 0.9600$$

Standard Deviation of the Estimate:

$$s(\hat{y}) = \left[\frac{(1 - r^2) \ \Sigma' y^2}{n - 2} \right]^{1/2} = 3.7522$$

95 Per Cent Confidence Limits of a Single Estimated Average Value, $\hat{Y}_{avg.} = \bar{y}$:

$$C.L._{95\%, \ d.f. = n-2} = t_{95\%, \ d.f. = n-2} \times s(\hat{Y})$$

where: d.f. are the degrees of freedom = 21.

$s(\hat{Y})$ is the estimated standard deviation for one inspection =

$$\left[s^2(\hat{y}) \left[1 + \frac{1}{n} + \frac{(\bar{x} - x)^2}{\Sigma' x^2} \right] \right]^{1/2} = 3.822$$

t = 2.080

C.L. = 2.080 x 3.822 = 7.95

Coefficient of Variation:

$$\% = \frac{s(\hat{y})}{\bar{y}} \times 100 = 1.926$$

DATA
SAMPLE PROCESSING TESTS

Section: 2
Date: 10/26/61

Item		Factory		Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		3.00		–	–	–	–
Undiluted Juice % Cane		70.03		64.49	70.18	73.60	63.18
Bagasse, % Cane		29.97		35.50	29.82	26.40	36.82
Brix % Cane		–		–	–	–	–
Pol, % Cane		–		–	–	–	–
Fiber % Cane		–		–	–	–	–
Brix Extracted, % Cane		12.30		11.48	12.56	13.54	10.92
Pol Extracted, % Cane		9.57		8.97	9.88	9.81	8.35
Brix Extracted, % Brix in Cane		–		–	–	–	–
Pol Extracted, % Pol in Cane		–		–	–	–	–
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	18.38	17.56	17.16	17.80	17.90	18.39	17.28
Pol	14.58	13.67	13.46	13.91	14.08	13.99	13.22
Purity	79.24	77.85	78.44	78.10	78.66	76.07	76.50
Bagasse: Brix		–		–	–	–	–
Pol		–		–	–	–	–
Moisture		–		–	–	–	–
Fiber		–		–	–	–	–

SAMPLE PROCESSING TESTS

Section 1
Date: 10/30/61

Item	Factory	Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane	3.5	–	–	–	–
Undiluted Juice, % Cane	70.22	60.99	70.32	73.64	63.02
Bagasse, % Cane	29.78	39.01	29.68	26.36	36.98
Brix, % Cane	–	–	–	–	–
Pol, % Cane	–	–	–	–	–
Fiber, % Cane	–	–	–	–	–
Brix Extracted % Cane	12.71	11.18	12.78	13.68	11.24
Pol Extracted % Cane	9.52	8.92	9.93	10.31	8.74
Brix Extracted, % Brix in Cane	–	–	–	–	–
Pol Extracted, % Pol in Cane	–	–	–	–	–

Item	Cr. J.	Und. J.	L.R. J.	Farrel-1	Farrel-2	Screw Press	Box Press
Juice: Brix	–	18.10	–	18.33	18.17	18.58	17.82
Pol	–	13.56	–	14.63	14.11	14.00	13.85
Purity	–	74.91	–	79.82	77.68	75.35	77.72
Bagasse: Brix		–		–	–	–	–
Pol		–		–	–	–	–
Moisture		–		–	–	–	–
Fiber		–		–	–	–	–

SAMPLE PROCESSING TESTS

Section: 2
Date: 10/31/61

Item		Factory		Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		5.25		–	–	–	–
Undiluted Juice, % Cane		70.62		63.97	71.06	73.40	62.40
Bagasse, % Cane		29.37		36.03	28.94	26.60	37.60
Brix, % Cane		15.37		–	15.64	16.13	14.23
Pol, % Cane		12.15		–	12.63	12.28	10.99
Fiber, % Cane		14.15		–	13.79	14.23	14.78
Brix Extracted, % Cane		13.21		12.18	13.51	14.10	10.90
Pol Extracted % Cane		10.44		9.81	10.91	10.75	8.42
Brix Extracted % Brix in Cane		85.93		–	86.37	87.59	76.60
Pol Extracted, % Pol in Cane		85.92		–	86.35	87.55	76.62
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	19.43	18.70	18.83	19.04	19.01	19.21	17.46
Pol	15.40	14.78	14.86	15.34	15.36	14.65	13.49
Purity	79.23	79.01	79.03	80.57	80.80	76.76	77.26
Bagasse: Brix		7.36		–	7.35	7.51	8.84
Pol		5.82		–	5.94	5.73	6.83
Moisture		44.45		–	45.00	39.00	51.85
Fiber		48.19		–	47.65	53.49	39.31

SAMPLE PROCESSING TESTS

Section: 2
Date: 11/2/61

Item		Factory		Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		4.15		–	–	–	–
Undiluted Juice, % Cane		70.90		62.84	69.72	73.48	62.06
Bagasse, % Cane		29.10		37.16	30.28	26.52	37.94
Brix, % Cane		15.16		–	15.43	15.87	14.76
Pol, % Cane		12.30		–	12.67	12.81	11.63
Fiber, % Cane		13.89		–	14.59	14.32	17.04
Brix Extracted, % Cane		12.89		11.38	13.15	14.01	11.06
Pol Extracted % Cane		10.46		9.45	10.81	11.31	8.72
Brix Extracted, % Brix in Cane		85.02		–	85.19	84.27	74.43
Pol Extracted, % Pol in Cane		85.05		–	85.26	88.30	74.95
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	19.13	18.18	17.32	18.10	18.85	19.07	17.82
Pol	15.36	14.75	14.00	15.04	15.50	15.38	14.05
Purity	80.29	81.13	80.83	83.07	82.23	80.65	78.82
Bagasse: Brix		7.80		–	7.53	7.02	9.74
Pol		6.33		–	6.19	5.66	7.68
Moisture		44.50		–	44.00	39.00	45.35
Fiber		47.70		–	48.17	53.98	44.91

SAMPLE PROCESSING TESTS

Section: 1
Date: 11/3/61

Item		Factory		Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		3.09		–	–	–	–
Undiluted Juice % Cane		71.08		64.45	70.05	75.40	63.11
Bagasse, % Cane		28.92		35.55	29.95	24.60	36.89
Brix, % Cane		14.28		–	14.45	14.79	13.26
Pol, % Cane		10.90		–	11.55	11.88	10.57
Fiber, % Cane		14.06		–	14.11	14.08	16.04
Brix Extracted, % Cane		12.44		11.45	12.44	13.33	10.49
Pol Extracted % Cane		9.50		9.15	9.94	10.72	8.36
Brix Extracted, % Brix in Cane		87.11		–	86.09	90.15	78.99
Pol Extracted, % Pol in Cane		87.32		–	86.10	90.19	78.65
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	17.70	17.50	16.80	17.77	17.76	17.68	16.62
Pol	13.82	13.37	12.72	14.19	14.19	14.21	13.24
Purity	78.05	76.40	75.69	79.80	79.90	80.37	79.66
Bagasse: Brix		6.37		–	6.70	5.91	7.51
Pol		4.82		–	5.35	4.75	5.98
Moisture		45.00		–	46.20	36.85	49.00
Fiber		48.63		–	47.10	57.24	43.49

SAMPLE PROCESSING TESTS

Section: 1
Date: 11/6/61

Item		Factory		Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		1.48		–	–	–	–
Undiluted Juice, % Cane		72.27		65.74	72.35	74.89	65.19
Bagasse, % Cane		27.73		34.26	27.65	25.11	34.81
Brix, % Cane		14.14		–	14.23	14.71	14.75
Pol, % Cane		10.40		–	11.18	11.63	12.02
Fiber, % Cane		13.28		–	10.94	14.29	13.71
Brix Extracted, % Cane		12.39		11.36	12.46	13.18	10.81
Pol Extracted % Cane		9.11		9.02	9.79	10.42	8.81
Brix Extracted, %Brix in Cane		87.60		–	87.53	89.57	73.29
Pol Extracted, % Pol in Cane		87.55		–	87.59	89.57	73.30
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	17.34	17.14	16.81	17.28	17.22	17.60	16.59
Pol	13.17	12.60	12.42	13.73	13.54	13.92	13.52
Purity	75.95	73.51	73.88	79.46	78.62	79.09	81.47
Bagasse: Brix		6.32		–	6.42	6.11	11.31
Pol		4.68		–	5.05	4.83	9.21
Moisture		45.80		–	54.00	37.00	49.30
Fiber		47.88		–	39.58	56.89	39.39

SAMPLE PROCESSING TESTS

Section: 2
Date: 11/7/61

Item		Factory		Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		6.78		-	-	-	-
Undiluted Juice, % Cane		70.49		63.97	71.83	74.21	61.19
Bagasse, % Cane		29.51		36.03	26.64	25.79	38.81
Brix, % Cane		14.65		-	14.42	15.03	14.52
Pol, % Cane		11.55		-	11.54	11.87	11.21
Fiber, % Cane		14.00		-	10.61	14.03	14.46
Brix Extracted, % Cane		12.44		11.26	12.54	13.21	10.17
Pol Extracted, % Cane		9.77		9.14	10.03	10.43	8.11
Brix Extracted, % Brix in Cane		84.88		-	86.93	87.92	70.04
Pol Extracted, % Pol in Cane		84.57		-	86.93	87.89	72.30
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	17.64	17.64	16.30	17.60	17.46	17.80	16.61
Pol	14.07	13.85	13.10	14.29	13.97	14.05	13.25
Purity	79.77	78.50	80.37	81.20	80.01	78.94	79.77
Bagasse: Brix		7.51		-	6.69	7.05	11.22
Pol		6.04		-	5.35	5.56	8.95
Moisture		45.05		-	55.66	38.55	51.50
Fiber		47.44		-	37.65	54.40	37.28

SAMPLE PROCESSING TESTS

Section: 2
Date: 11/9/61

Item	Cr. J.	Factory	L.R. J.	Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		11.0		–	–	–	–
Undiluted Juice, % Cane		70.56		64.81	72.66	73.87	60.65
Bagasse, % Cane		29.44		35.19	27.34	26.13	39.35
Brix, % Cane		14.45		–	15.00	15.29	13.77
Pol, % Cane		11.55		–	12.10	11.94	11.39
Fiber, % Cane		13.84		–	12.51	14.08	16.07
Brix Extracted % Cane		12.12		11.33	12.90	13.38	10.17
Pol Extracted, % Cane		9.74		9.24	10.37	10.45	8.41
Brix Extracted, % Brix in Cane		83.87		–	85.97	87.57	73.85
Pol Extracted, % Pol in Cane		84.30		–	85.72	87.56	73.85
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	17.93	17.18	17.06	17.48	17.76	18.12	16.77
Pol	14.28	13.80	13.24	14.26	14.27	14.15	13.88
Purity	79.62	80.33	77.61	81.61	80.35	78.09	82.77
Bagasse: Brix		7.92		–	7.68	7.26	9.16
Pol		6.15		–	6.17	5.67	7.58
Moisture		45.08		–	46.55	38.95	50.00
Fiber		47.00		–	45.77	53.89	40.84

SAMPLE PROCESSING TESTS

Section: 1
Date: 11/10/61

Item		Factory		Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		3.74		–	–	–	–
Undiluted Juice, % Cane		71.34		65.82	71.51	75.19	62.72
Bagasse, % Cane		28.66		34.18	28.49	24.81	37.28
Brix, % Cane		14.30		–	14.78	14.57	12.94
Pol, % Cane		10.97		–	11.69	11.46	10.27
Fiber, % Cane		13.61		–	13.22	14.16	15.30
Brix Extracted, % Cane		12.36		11.49	12.75	13.11	10.59
Pol Extracted, % Cane		9.49		9.22	10.09	10.31	8.40
Brix Extracted, % Brix in Cane		86.44		–	86.29	89.99	81.85
Pol Extracted, % Pol in Cane		86.02		–	86.26	89.98	81.82
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	17.69	17.33	16.68	17.46	17.83	17.44	16.88
Pol	14.03	13.30	12.77	14.01	14.11	13.71	13.40
Purity	79.31	76.74	76.38	80.24	79.14	78.61	79.38
Bagasse: Brix		6.76		–	7.11	5.90	6.30
Pol		5.16		–	5.63	4.64	5.00
Moisture		45.75		–	46.50	37.00	52.65
Fiber		47.49		–	46.39	57.10	41.05

SAMPLE PROCESSING TESTS

Section: 1
Date: 11/13/61

Item		Factory		Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		1.76		–	–	–	–
Undiluted Juice, % Cane		73.26		64.53	73.27	76.59	61.44
Bagasse, % Cane		26.74		35.47	26.73	23.41	38.56
Brix, % Cane		13.71		–	14.34	13.63	13.87
Pol, % Cane		10.32		–	10.98	10.26	9.84
Fiber, % Cane		11.96		–	11.76	12.60	14.61
Brix Extracted, % Cane		12.12		10.78	12.46	12.40	9.62
Pol Extracted, % Cane		9.12		8.43	9.54	9.33	7.36
Brix Extracted, % Brix in Cane		88.40		–	86.90	90.96	74.74
Pol Extracted, % Pol in Cane		88.37		–	86.90	90.97	74.80
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	16.71	16.54	16.35	16.71	17.01	16.19	15.66
Pol	12.56	12.45	12.32	13.05	13.03	12.19	11.99
Purity	75.16	75.27	75.35	78.10	76.60	75.26	76.53
Bagasse: Brix		5.95		–	7.02	5.28	8.42
Pol		4.48		–	5.38	3.97	6.44
Moisture		49.32		–	49.00	40.90	53.70
Fiber		44.73		–	43.98	53.82	37.88

Note: Trash on cane appeared greater than trash inspection shows.

SAMPLE PROCESSING TESTS

Section: 2
Date: 11/14/61

Item		Factory		Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		6.20		–	–	–	–
Undiluted Juice, % Cane		71.23		63.26	73.47	74.60	59.31
Bagasse, % Cane		28.77		36.74	26.53	25.40	40.69
Brix, % Cane		14.80		–	14.09	14.00	13.18
Pol, % Cane		9.98		–	11.05	11.08	10.46
Fiber, % Cane		13.92		–	12.54	13.76	14.42
Brix Extracted, % Cane		12.58		10.15	12.22	12.28	9.14
Pol Extracted, % Cane		8.34		7.59	9.59	9.72	7.25
Brix Extracted, % Brix in Cane		84.99		–	86.75	87.72	69.36
Pol Extracted, % Pol in Cane		83.55		–	86.75	87.73	69.37
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	19.26	17.66	16.07	16.04	16.64	16.47	15.42
Pol	11.96	11.71	11.65	12.00	13.05	13.03	12.24
Purity	62.10	66.31	72.50	74.81	78.43	79.13	79.38
Bagasse: Brix		7.73		–	7.04	6.77	9.92
Pol		5.71		–	5.52	5.36	7.87
Moisture		43.87		–	45.70	39.05	54.64
Fiber		48.40		–	47.26	54.18	35.44

Note: Considerable sediment in factory crusher and mixed juice samples.

SAMPLE PROCESSING TESTS

Section: 2
Date: 11/16/61

Item		Factory		Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		13.08		–	–	–	–
Undiluted Juice, % Cane		71.85		65.08	71.72	75.93	59.50
Bagasse, % Cane		28.15		34.92	28.28	24.07	40.50
Brix, % Cane		13.41		–	13.22	13.39	13.18
Pol, % Cane		10.14		–	9.72	10.18	10.54
Fiber, % Cane		12.35		–	12.68	12.98	14.89
Brix Extracted, % Cane		11.13		10.36	11.28	11.95	9.28
Pol Extracted, % Cane		8.42		7.95	8.30	9.09	7.42
Brix Extracted, % Brix in Cane		83.03		–	85.32	89.29	70.34
Pol Extracted, % Pol in Cane		83.07		–	85.35	89.29	70.36
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	15.97	15.49	14.88	15.92	15.72	15.74	15.59
Pol	12.32	11.72	11.36	12.21	11.57	11.97	12.47
Purity	77.15	75.63	76.37	76.70	73.60	76.05	79.99
Bagasse: Brix		8.07		–	6.86	5.96	9.64
Pol		6.10		–	5.05	4.53	7.71
Moisture		48.05		–	48.30	40.10	53.60
Fiber		43.88		–	44.84	53.94	36.76

SAMPLE PROCESSING TESTS

Section: 1
Date: 11/17/61

Item		Factory		Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		7.69		–	–	–	–
Undiluted Juice, % Cane		71.47		62.63	70.57	74.14	56.01
Bagasse, % Cane		28.53		37.37	29.43	25.86	43.99
Brix, % Cane		14.11		–	13.46	14.09	11.07
Pol, % Cane		10.80		–	10.65	11.33	8.99
Fiber, % Cane		13.30		–	13.18	13.21	17.55
Brix Extracted, % Cane		12.28		10.70	11.78	12.51	8.77
Pol Extracted, % Cane		9.45		8.72	9.33	10.06	7.12
Brix Extracted, % Brix in Cane		87.04		–	87.51	88.77	79.27
Pol Extracted, % Pol in Cane		87.52		–	87.59	88.81	79.27
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	17.09	17.19	16.81	17.08	16.69	16.87	15.66
Pol	13.76	13.22	12.39	13.92	13.22	13.56	12.71
Purity	80.51	76.90	73.71	81.50	79.21	80.38	81.16
Bagasse: Brix		6.40		–	5.72	6.11	5.20
Pol		4.72		–	4.53	4.91	4.22
Moisture		47.00		–	49.50	42.80	54.90
Fiber		46.60		–	44.78	51.09	39.90

SAMPLE PROCESSING TESTS

Section: 1
Date: 11/20/61

Item		Factory		Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		4.37		-	-	-	-
Undiluted Juice, % Cane		70.58		63.54	67.96	75.47	56.57
Bagasse, % Cane		29.42		36.46	32.04	24.53	43.43
Brix, % Cane		14.69		-	14.23	15.28	12.96
Pol, % Cane		10.99		-	11.34	12.22	10.40
Fiber, % Cane		13.80		-	13.79	13.73	15.95
Brix Extracted, % Cane		12.59		11.20	12.02	13.62	9.37
Pol Extracted, % Cane		9.41		8.88	9.59	10.89	7.51
Brix Extracted, % Brix in Cane		85.77		-	84.52	89.16	72.29
Pol Extracted, % Pol in Cane		85.65		-	84.56	89.15	72.27
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	18.02	17.85	16.80	17.62	17.69	18.05	16.56
Pol	14.07	13.33	12.69	13.99	14.10	14.43	13.28
Purity	76.05	74.68	75.53	79.37	79.71	79.94	80.16
Bagasse: Brix		7.10		-	6.87	6.74	8.28
Pol		5.36		-	5.47	5.39	6.64
Moisture		46.00		-	50.10	37.30	55.00
Fiber		46.90			43.03	55.96	36.72

SAMPLE PROCESSING TESTS

Section: 2
Date: 11/21/61

Item		Factory		Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		3.12		–	–	–	–
Undiluted Juice, % Cane		69.70		65.51	71.35	73.44	55.20
Bagasse, % Cane		30.30		34.49	28.65	26.56	44.80
Brix, % Cane		15.19		–	15.33	15.23	14.05
Pol, % Cane		12.10		–	12.41	12.33	11.53
Fiber, % Cane		13.38		–	12.90	13.55	15.68
Brix Extracted, % Cane		12.59		11.56	13.07	13.38	9.26
Pol Extracted, % Cane		10.04		9.44	10.58	10.83	7.60
Brix Extracted, % Brix in Cane		82.86		–	85.29	87.83	65.89
Pol Extracted, % Pol in Cane		82.90		–	85.25	87.83	65.90
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	18.10	18.06	17.68	17.65	18.33	18.22	16.77
Pol	14.68	14.40	13.28	14.41	14.82	14.75	13.77
Purity	81.10	79.71	75.54	81.64	80.85	80.95	82.11
Bagasse: Brix		8.59		–	7.89	6.98	10.70
Pol		6.82		–	6.38	5.65	8.78
Moisture		47.24		–	47.10	42.00	54.30
Fiber		44.17		–	45.01	51.02	35.00

SAMPLE PROCESSING TESTS

Section: 1
Date: 11/27/61

Item	Cr. J.	Factory Und. J.	L.R. J.	Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		4.30		–	–	–	–
Undiluted Juice, % Cane		69.16		61.65	68.39	73.11	57.80
Bagasse, % Cane		30.84		38.35	31.61	26.89	42.20
Brix, % Cane		14.22		–	14.10	14.82	13.16
Pol, % Cane		10.64		–	10.60	11.08	9.98
Fiber, % Cane		14.79		–	15.09	15.14	15.87
Brix Extracted, % Cane		12.21		11.12	12.32	13.50	9.78
Pol Extracted, % Cane		9.22		8.55	9.25	10.09	7.42
Brix Extracted, % Brix in Cane		85.86		–	87.37	91.09	74.29
Pol Extracted, % Pol in Cane		86.68		–	87.36	91.06	74.38
Juice: Brix	18.48	17.65	16.68	18.05	18.01	18.46	16.92
Pol	14.15	13.33	11.76	13.87	13.53	13.80	12.84
Purity	76.57	75.55	70.47	76.84	75.13	74.76	75.91
Bagasse: Brix		6.53		–	5.65	4.91	8.00
Pol		4.60		–	4.24	3.67	6.07
Moisture		45.50		–	46.60	38.80	54.40
Fiber		47.97		–	47.75	56.29	37.60

SAMPLE PROCESSING TESTS

Section: 2
Date: 11/28/61

Item		Factory		Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		2.82		–	–	–	–
Undiluted Juice, % Cane		71.42		63.78	72.33	76.22	59.93
Bagasse, % Cane		28.58		36.22	27.67	23.78	40.61
Brix, % Cane		14.08		–	13.97	14.01	12.99
Pol, % Cane		11.28		–	11.14	11.90	10.86
Fiber, % Cane		13.52		–	13.15	14.45	17.11
Brix Extracted % Cane		12.20		11.03	12.25	12.99	9.69
Pol Extracted % Cane		9.83		9.21	9.77	10.37	8.10
Brix Extracted, % Brix in Cane		86.63		–	87.72	92.67	74.40
Pol Extracted, % Pol in Cane		87.15		–	87.70	92.65	74.45
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	17.77	17.08	16.49	17.29	16.94	17.04	16.17
Pol	14.17	13.76	12.69	14.44	13.51	13.60	13.52
Purity	79.71	80.26	76.93	83.52	79.75	79.81	83.61
Bagasse: Brix		6.58		–	6.19	4.33	8.12
Pol		5.07		–	4.94	3.46	6.79
Moisture		46.10		–	46.30	35.90	49.75
Fiber		47.32		–	47.51	60.77	42.13

SAMPLE PROCESSING TESTS

Section: 2
Date: 11/30/61

Item		Factory		Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		4.85		–	–	–	–
Undiluted Juice, % Cane		68.06		61.07	66.04	70.43	52.56
Bagass, % Cane		31.94		38.93	33.96	29.57	47.44
Brix, % Cane		14.20		–	15.53	15.85	14.41
Pol, % Cane		11.91		–	13.33	13.24	12.90
Fiber, % Cane		15.60		–	15.97	16.17	16.22
Brix Extracted, % Cane		12.39		11.90	12.80	13.75	9.66
Pol Extracted % Cane		10.54		10.12	10.99	11.49	8.65
Brix Extracted, % Brix in Cane		87.29		–	82.39	86.74	67.07
Pol Extracted, % Pol in Cane		88.49		–	82.39	86.74	67.07
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	19.39	18.21	18.08	19.48	19.38	19.52	18.39
Pol	16.38	15.49	14.49	16.56	16.64	16.31	16.46
Purity	84.48	85.06	80.14	85.01	85.86	83.56	89.51
Bagasse: Brix		5.65		–	8.06	7.10	10.00
Pol		4.30		–	6.92	5.93	8.95
Moisture		45.51		–	44.90	38.20	55.80
Fiber		48.84		–	47.04	54.70	34.20

SAMPLE PROCESSING TESTS

Section: 1
Date: 12/1/61

Item	Cr. J.	Factory	L.R. J.	Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		6.67		–	–	–	–
Undiluted Juice, % Cane		70.94		65.36	70.05	75.92	57.49
Bagasse, % Cane		29.06		34.63	29.95	24.08	42.51
Brix, % Cane		14.67		–	14.48	15.04	12.27
Pol, % Cane		11.83		–	11.73	12.39	10.18
Fiber, % Cane		13.56		–	13.66	13.49	15.62
Brix Extracted % Cane		12.54		11.62	12.35	13.61	9.28
Pol Extracted % Cane		10.16		9.69	10.01	11.21	7.70
Brix Extracted % Brix in Cane		35.50		–	85.32	90.45	75.66
Pol Extracted, % Pol in Cane		86.03		–	85.32	90.50	75.60
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	18.20	17.68	17.05	17.77	17.62	17.93	16.16
Pol	14.95	14.32	13.36	14.83	14.29	14.77	13.38
Purity	82.14	80.94	78.36	83.46	81.10	82.38	82.80
Bagasse: Brix		7.33		–	7.09	5.96	7.04
Pol		5.74		–	5.75	4.91	5.83
Moisture		46.00		–	47.30	38.00	56.20
Fiber		46.67		–	45.61	56.04	36.76

SAMPLE PROCESSING TESTS

Section: 1
Date: 12/4/61

Item		Factory		Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		7.32		–	–	–	–
Undiluted Juice, % Cane		68.61		60.06	68.30	71.33	52.28
Bagasse, % Cane		31.39		39.94	31.70	28.67	47.72
Brix, % Cane		14.78		–	14.92	15.20	13.13
Pol, % Cane		12.07		–	12.54	12.38	11.37
Fiber, % Cane		14.55		–	14.71	15.55	18.84
Brix Extracted, % Cane		12.38		10.90	12.63	13.59	9.09
Pol Extracted, % Cane		10.18		9.48	10.62	11.06	7.87
Brix Extracted, % Brix in Cane		83.76		–	84.64	89.46	69.22
Pol Extracted, % Pol in Cane		84.37		–	84.68	89.35	69.20
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	19.16	18.04	17.78	18.16	18.49	19,05	17.37
Pol	16.12	14.84	14.01	15.79	15.56	15.51	15.05
Purity	84.14	82.29	78.80	86.95	84.15	81.42	86.64
Bagasse: Brix		7.64		–	7.20	5.58	8.48
Pol		6.02		–	6.06	4.60	7.35
Moisture		46.00		–	46.40	40.20	52.05
Fiber		46.36		–	46.40	54.22	39.47

SAMPLE PROCESSING TESTS

Section: 2
Date: 12/5/61

Item		Factory		Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		2.60		–	–	–	–
Undiluted Juice, % Cane		69.81		63.76	68.91	71.66	50.85
Bagasse, % Cane		30.19		36.24	31.09	28.34	49.15
Brix, % Cane		14.97		–	14.80	15.34	12.99
Pol, % Cane		12.24		–	12.42	12.85	10.80
Fiber, % Cane		14.07		–	14.42	14.45	17.89
Brix Extracted % Cane		12.69		11.53	12.53	13.32	8.71
Pol Extracted % Cane		10.56		9.87	10.51	11.16	7.24
Brix Extracted, % Brix in Cane		84.75		–	84.64	86.86	67.04
Pol Extracted, % Pol in Cane		86.32		–	84.62	86.85	67.05
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	18.82	18.18	17.75	18.08	18.18	18.60	17.13
Pol	15.86	15.13	13.01	15.48	15.26	15.57	14.24
Purity	84.27	83.22	73.30	85.62	83.94	83.71	83.11
Bagasse: Brix		7.57		–	7.31	7.12	8.71
Pol		5.55		–	6.14	5.96	7.24
Moisture		45.83		–	46.30	41.90	54.90
Fiber		46.60		–	46.39	50.98	36.39

SAMPLE PROCESSING TESTS

Section: 2
Date: 12/7/61

Item		Factory		Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		7.62		–	–	–	–
Undiluted Juice, % Cane		66.84		60.00	65.60	68.22	51.76
Bagasse, % Cane		33.16		40.00	34.40	31.78	48.24
Brix, % Cane		15.21		–	14.93	15.46	13.95
Pol, % Cane		12.69		–	12.87	13.26	11.90
Fiber, % Cane		14.84		–	15.70	16.49	18.03
Brix Extracted, % Cane		12.44		11.38	12.40	13.14	8.89
Pol Extracted, % Cane		10.44		9.81	10.69	11.27	7.59
Brix Extracted, % Brix in Cane		81.77		–	83.01	84.99	63.76
Pol Extracted, % Pol in Cane		82.29		–	83.05	84.99	63.77
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	19.40	18.61	18.00	18.96	18.90	19.26	17.18
Pol	16.47	15.62	14.55	16.35	16.29	16.52	14.66
Purity	84.90	83.94	80.81	86.20	86.19	85.77	85.33
Bagasse: Brix		8.37		–	7.36	7.30	10.48
Pol		6.77		–	6.34	6.26	8.94
Moisture		46.87		–	47.00	40.80	52.15
Fiber		44.76		–	45.64	51.90	37.37

SAMPLE PROCESSING TESTS

Section: 1
Date: 12/8/61

Item		Factory		Farrel-1	Farrel-2	Screw Press	Box Press
Trash, % Cane		12.00		–	–	–	–
Undiluted Juice, % Cane		69.20		61.83	68.19	71.43	49.92
Bagasse, % Cane		30.80		38.17	31.81	28.57	50.08
Brix, % Cane		14.96		–	14.64	14.58	11.16
Pol; % Cane		12.45		–	12.36	12.37	9.58
Fiber, % Cane		14.56		–	14.27	14.97	21.16
Brix Extracted % Cane		12.82		11.69	12.71	12.98	8.51
Pol Extracted % Cane		10.74		10.25	10.74	11.01	7.31
Brix Extracted, % Brix in Cane		85.72		–	86.86	89.04	76.29
Pol Extracted, % Pol in Cane		86.25		–	86.89	88.96	76.28
	Cr. J.	Und. J.	L.R. J.				
Juice: Brix	18.92	18.53	18.07	18.91	18.64	18.18	17.06
Pol	16.01	15.52	14.42	16.58	15.75	15.41	14.63
Purity	84.62	83.76	79.97	87.68	84.47	84.76	85.76
Bagasse: Brix		6.94		–	6.05	5.58	5.29
Pol		5.55		–	5.11	4.73	4.54
Moisture		45.30			49.10	42.00	52.45
Fiber		47.26			44.85	52.42	42.26

VITA

John J. Seip was born in Erie, Pennsylvania, on April 8, 1917. He received his grammar school and high school education in Allentown, Pennsylvania. He attended Louisiana State University from 1937 to 1941, receiving the B.S. degree in Chemical Engineering in 1943. After serving four years in the armed forces, he returned to Louisiana State University to complete his M.S. degree in Chemical Engineering in 1947.

Following work in the raw sugar and the petroleum refining industries he returned to Louisiana State University in September of 1959 for further graduate study. He is presently a candidate for the Ph.D degree in Chemical Engineering at Louisiana State University, and is currently serving on the staff of the Chemical Engineering Department.

EXAMINATION AND THESIS REPORT

Candidate: John Jacob Seip

Major Field: Chemical Engineering

Title of Thesis: A Method of Determining Sugar Cane Quality in Louisiana.

Approved:

Major Professor and Chairman

Max Goodrich

Dean of the Graduate School

EXAMINING COMMITTEE:

J. B. Cordiner

Jesse Coates

W. E. Ralph

S. W. Preston

Bernard S. Groseburg

Date of Examination:

January 9, 1963